DIVIDING

Harold Hall

WORKSHOP PRACTICE SERIES

NUMBER 37

DIVIDING

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Special Interest Model Books

Special Interest Model Books Ltd.
P.O.Box 327
Poole
Dorset
BH15 2RG
England

First published by Special Interest Model Books Ltd. 2005

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ISBN 1-85486-238-3

www.specialinterestmodelbooks.co.uk

Printed and bound in Malta, by Interprint Limited

CONTENTS

Preface

Whilst in the home workshop, dividing is not a frequent operation, there are though many ways of carrying out the task. This is quite different to the major workshop activities where round items will invariably be the domain of the lathe and rectangular items, that of the milling machine, with the shaper chipping in in a few cases.

Dividing, however, can be carried out on the lathe, milling machine and even the drilling machine. It is though, the wide range of accessories and methods that make the task a daunting one for many workshop owners.

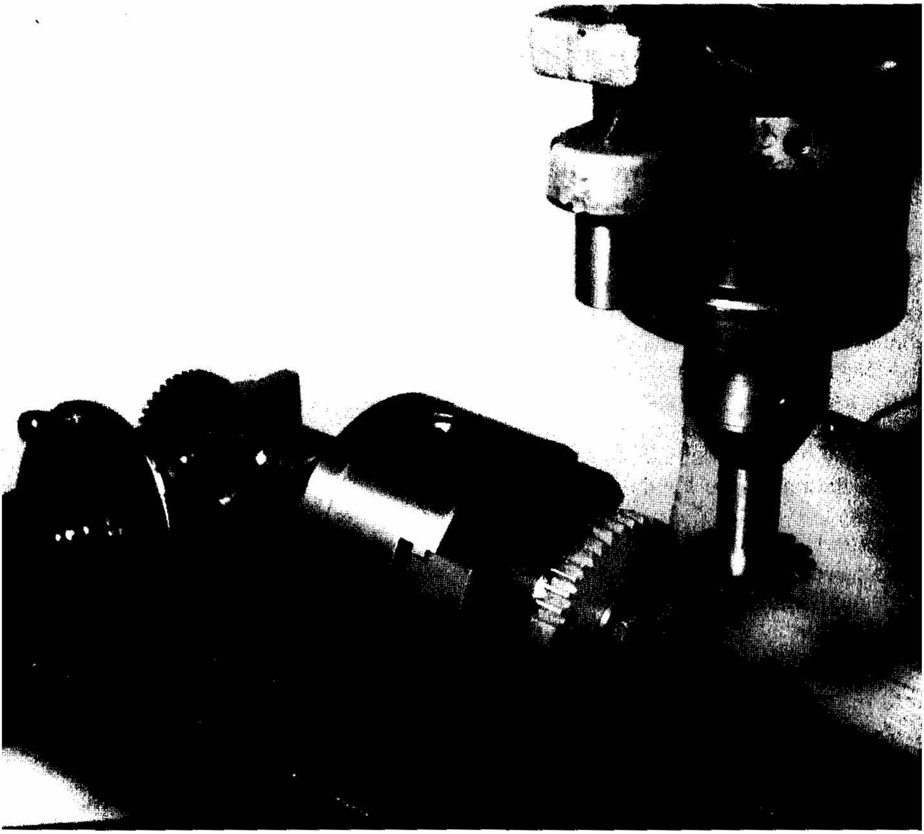
In addition to choice of method, setting it up correctly will often require recourse to some mathematics. These, mathematically, are fortunately quite simple, but some understanding of their purpose is essential. The book can therefore be loosely divided into three sections.

1. The machinery
2. The methods
3. The mathematics

In addition to the explanations of the equipment and how it is used, the book also includes some designs for items that can be made in the workshop itself. In the main these just give the necessary drawings but with some manufacturing tips where considered desirable.

Dividing will almost certainly be a small proportion of workshop activity, but without the required provisions, and understanding, some projects will either be impossible, very difficult or of a very inferior quality.

Harold Hall January 2005



1. Cutting a gear using a shop made dividing head.

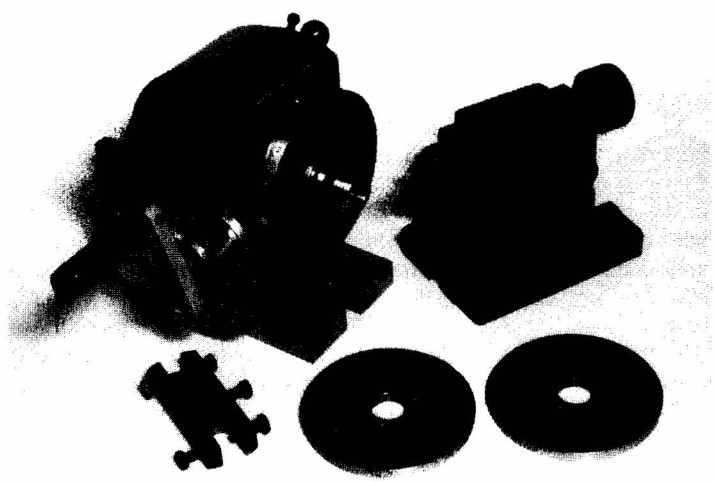
Chapter 1

An Introduction to Dividing

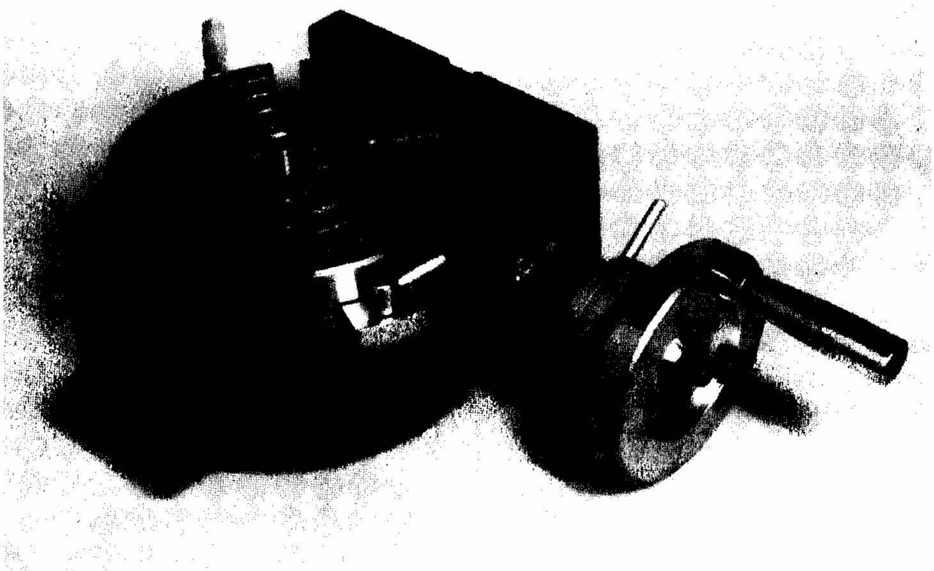
Whilst the term dividing can be applied to a range of values, typically length, weight, angle, even voltage, in the metal working workshop, home or commercial, it is used almost entirely for angular division. The range of uses will be varied but with a high proportion of the activity limited to a small range of tasks, making gears **Photo 1**, dials, placing holes on a PCD (pitch circle diameter) and producing squares and hexagons, typically for application of a spanner to a turned component.

The methods of achieving the division will though be large and varied and range from the simple to the complex, each finding a use in at least some workshops. Perhaps not fully appreciated is the fact that simple methods are not just limited to lower numbers, in some applications, dials typically, even higher numbers can be achieved without any expense being incurred.

For many years the predominant



2. A commercial semi universal dividing head with tailstock



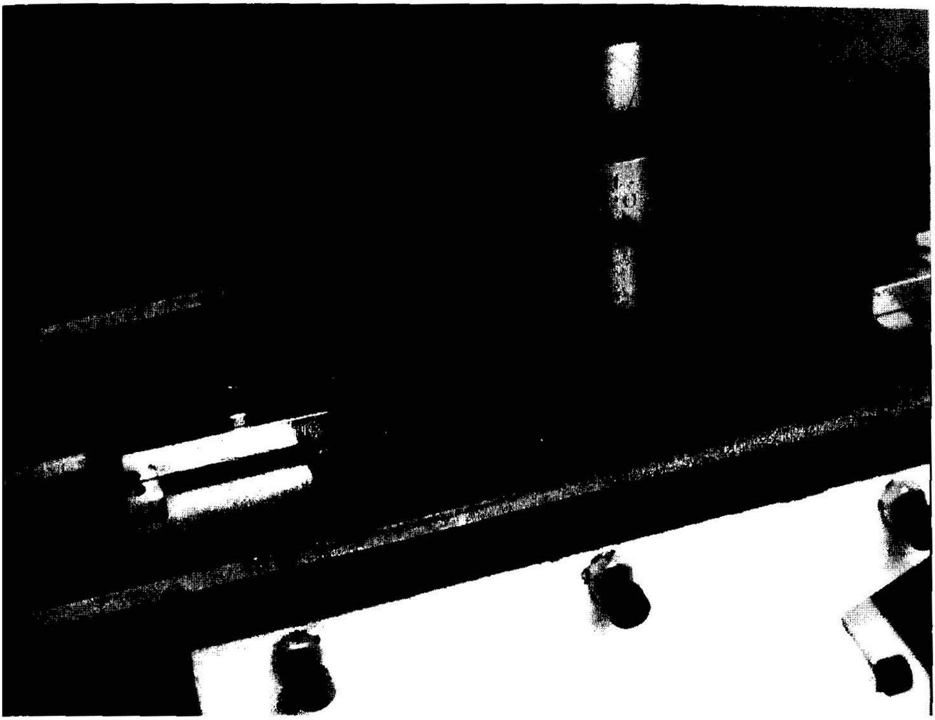
3. A rotary table, useful for dividing in some applications.

method in the home workshop, at least for the simple task, was to make attachments for the lathe spindle to control angle of rotation. Today, greater availability and reduced price of modern accessories have made this less necessary. There are still instances where it is worth considering. Carrying out some work on a component in the lathe mounted chuck having just been machined there, may be quicker than setting up the dividing head on the milling machine and transferring the component to this.

If dividing is to become an important activity then acquiring a semi-universal dividing head, commercially made **Photo 2** or made in the workshop, should be considered. As a dividing head will likely get only limited use and the expense as a result difficult to justify, the latter may well be the way to proceed. Because of this, designs for two shop made items are included in Chapters 7 and 8.

Using a rotary table **Photo 3** is also a possibility and whilst this item of equipment is primarily intended for the machining of curved surfaces and slots and the like, its use for dividing is also possible.

When placing holes on a PCD, working out the X and Y co-ordinates of each hole and using these to place the holes using the milling machine table dials as shown in **Photo 4** can give a very accurate result. This can be particularly useful if requiring a dividing plate for use on the dividing head especially if for a one off application.



4. Making a dividing plate on a milling machine table using calculated X and Y co-ordinates.

Chapter 2

The Machinery

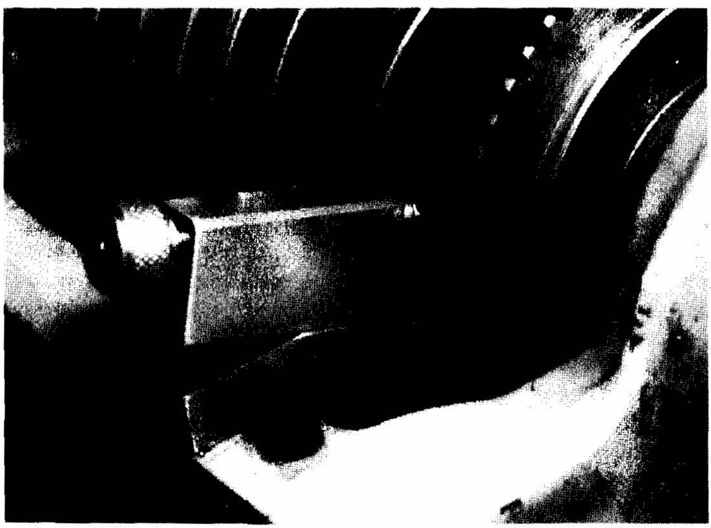
The equipment available for dividing applications, even for the home workshop, is very varied, though in general terms, the methods can be reduced to just five.

Using the lathe spindle.
Using a dividing head.
Using a rotary table.
Using an indexer.
Dividing with no special equipment.

The latter will be dealt with when discussing the actual processes. As will be seen however the demarcation between these is not always that clear, especially methods 2, 3 and 4.

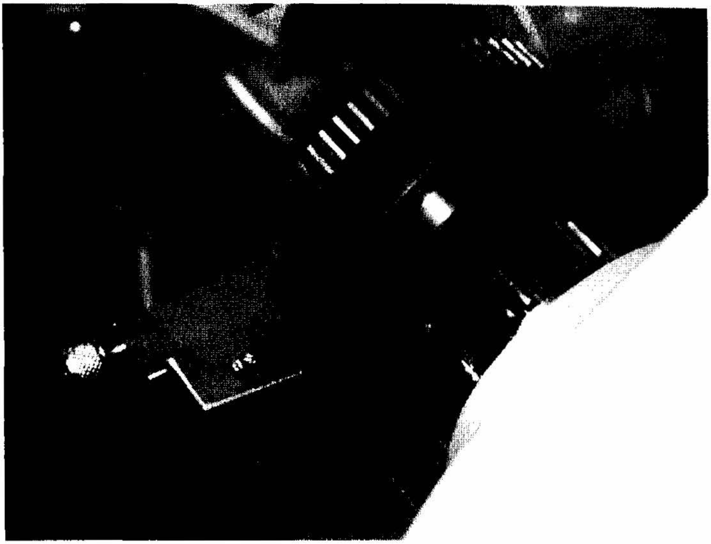
1. Using the lathe spindle

This primarily consists of indexing the spindle using a detent locating into the teeth of a gear or holes in a disc that is mounted



1. Indexing using the lathe's Bull wheel

2. *Indexing using a gear on the rear end a lathe's headstock.*

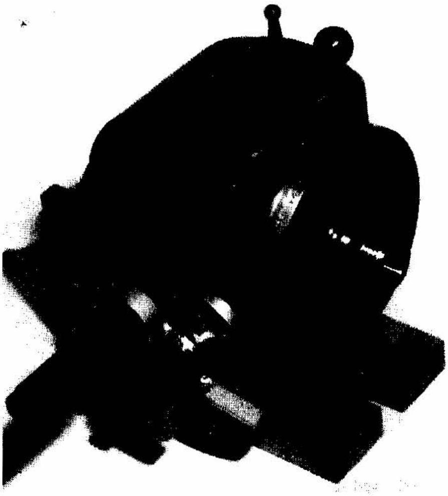


on the lathe spindle. The latter may even be in the chuck's backplate. The most common is to use the gear in the back gear assembly that is rigidly fitted to the spindle, frequently referred to as the bull wheel. One well-known lathe manufacture does provide this facility and others may do also, it is though more common for the lathe owner to adapt the lathe to provide this function. **Photo 1** shows a typical shop made item.

One aspect of the lathe that may make the method a non starter is the number of teeth on the gear, if say this was 49 there would be no useful divisions, only 7 being available. The gear in the above example has 60 teeth and will provide 2, 3, 4, 5, 6, 10, 12, 15, 20, 30 and 60 divisions. If a forked detent is used this could be increased to include 8, 24, 40 and 120 also. More about forked detents later.

If your lathe does not have a suitable bull wheel then mounting a gear on the rear of the lathe spindle, as illustrated in **Photo 2**, and erecting a detent from some convenient point, probably the changewheels quadrant, will overcome the limitation. Even where the lathe has a suitable bull wheel this arrangement will increase the number of possible divisions. Mounting the gear, or even a dividing plate, is not difficult and a simple method for achieving this is illustrated in the section on shop made items in Chapter 6. A similar method for simpler numbers is to drill the chuck back plate with a series of holes around its periphery using a detent mounted off the lathe bed to locate in these.

A limitation of all of the above methods is that there is no facility to lock the spindle in the set position, relying solely on the detent to hold it in place. Backlash in the detent assembly will permit some variation in the position set, and more important, movement during the machining operation. It is though quite adequate for many tasks as will be seen through the book.



3. A semi universal head.

2. Using a dividing head

This is the most complex and costly of the dividing techniques covered in this book but as would be expected the most versatile; **Photo 3** shows a typical example. As well as being used horizontally it can be set up vertically, **Photo 4**, or any angle in between. The first point to note is that the rotating spindle, which carries the workpiece, can be firmly locked in any position. This helps to minimise errors of position but more importantly permits quite heavy machining operations to take place.

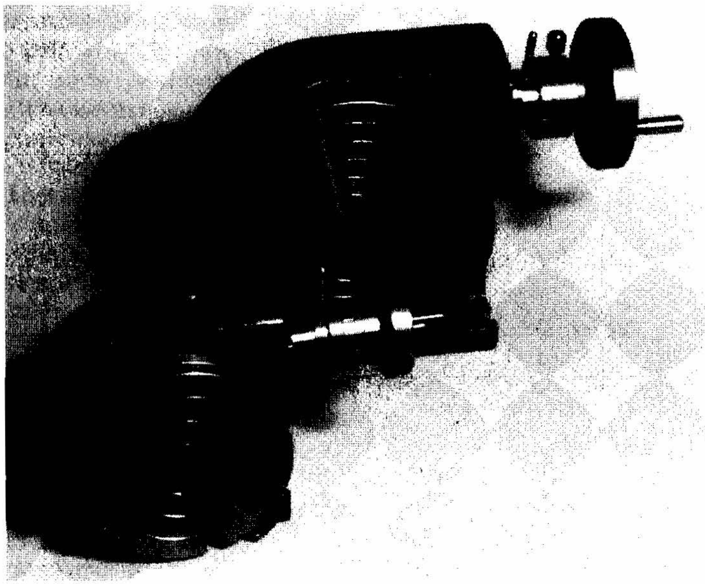
Rotation of the spindle is achieved using a worm and worm wheel such that many turns are required at the manual input, for one turn at the dividing head output. A ratio of 40:1 appears most common but others may be available.

A dividing plate is fitted to the body of the device and the input spindle fitted with an arm and detent for locating in the dividing plate holes so that repetitive input can be achieved precisely. Dividing plates are available with a wide range of hole numbers. By choosing the correct one and with the 40:1 ratio the required division can be obtained by bypassing the appropriate number of holes for each division. However, even with a wide range of dividing plates there will be many divisions that cannot be achieved, particularly at the higher numbers. At one time dividing plates were very expensive but modern computer controlled production methods enable the punched sheet steel variety to be produced very cheaply.

Mounting the workpiece onto the dividing head follows very closely that of the lathe having the facility for fitting a faceplate or chuck, Also a centre can be fitted and with a tailstock, either supplied or available as an accessory, between centres work can be carried out.

4. A semi universal head can also be used vertically

5. Two shop made rotary tables.



2a. Universal dividing head

Universal dividing heads, (the above being known as semi-universal) are capable of a much wider range of divisions, typically all values between 2 and 380 and many higher values. This being achieved by the addition of a gear chain between the dividing head spindle and the dividing plate itself, but whilst still using the limited number of dividing plate values normally supplied.

The drive from the manual crank handle to the dividing head spindle is still via the worm and worm wheel. However, a gear chain from the rear end of the head spindle is then arranged to rotate the dividing plate itself by a small amount. This has the effect of marginally altering the rotation of the crank handle for a given number of holes. The outcome of this is that divisions not obtainable with the semi-universal head can be set up. The gear chain is set up for differing ratios, rather like the changewheels used on a lathe for screw cutting.

The gear chain also has another purpose and whilst too complex to be discussed in detail it is worth noting for completeness. Rather than being between spindle and dividing plate, the gears are set up between spindle and one end of the milling machine leadscrew resulting in the output from the dividing head rotating as the machine table is traversed. By this method helical flutes can be cut. Should this be of interest, search out other reading on the subject.

3. Using a Rotary table

The demarcation between a dividing head and the rotary table is rather blurred both having common features. The major one being both have a worm and worm wheel

6. Commercial rotary tables often have a dividing plate assembly available as an accessory.

between the manual input and the rotation of the workpiece, though there would appear to be more variation in the ratio's available, 40, 60 and 90:1 all being common. The major differences are in the provision for work holding and in most cases the method of determining the input value. For work holding, rather than having facilities for either a faceplate or chuck, the rotary table has a T slotted round table, **Photo 5**. Input to the worm is determined by reference to a calibrated dial rather like that of the leadscrew dials on a lathe or milling machine. In dividing applications this only works well if the required input falls exactly on a calibration, otherwise errors will result.

Rotary tables have therefore only limited use where dividing is required, their main use being for machining curved surfaces and curved slots. Placing holes on a PCD is also practicable for lower numbers where high precision is not required. It would though be questionable for a large number of holes on a PCD when making a dividing plate or for producing a gear. Most will also be suitable for vertical mounting. Also available as an extra in some cases is a dividing plate mounting arrangement as seen in **Photo 6**. With this available there is little difference between a dividing head and a rotary table, other than the provision for workpiece mounting. If the budget will stretch to it and you purchase both a dividing head and a rotary table from the same manufacturer, it is likely that the dividing plate assembly on the head will also fit the rotary table. Its tailstock is also likely to be usable, as these are adjustable for height, see **Photo 2** Chapter 1.

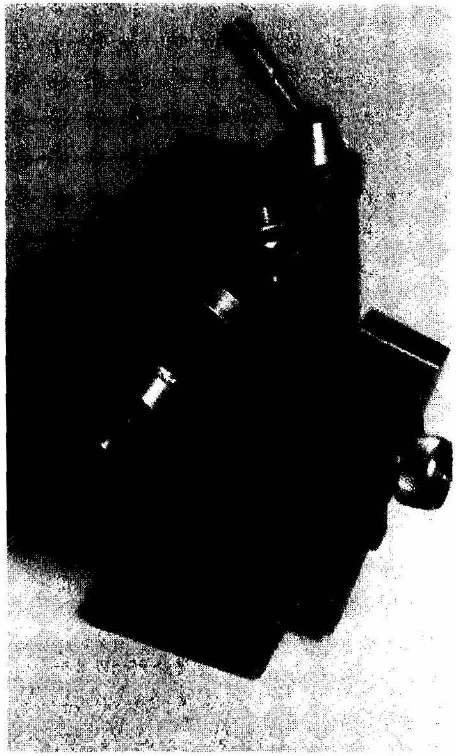
4. Using an indexer

This is a very simple form of dividing head having a rotating work holding device that is rotated directly by hand, there being no worm and wormwheel. Angle of rotation for each division is either set by reference to a 360deg. calibration round the edge of the table or by the use of a number of holes round the table, maybe 24, into which a detent locates giving a range of common divisions.

Indexers are normally fitted with only one method of work holding, being either a three-jaw chuck or collets. This severely limits the tasks they can perform. Some are also suitable for horizontal mounting though of course they could be used with a substantial angle plate. Commercial items are not really appropriate for the average home workshop.

Home workshop made items

The comments above regarding dividing heads and Indexers are made primarily with commercially available items in mind. They do though in many cases also apply to items made in the home workshop. However, many home workshop owners do find much simpler designs adequate for their needs, that in **Photo 7** being an example. Whilst for this the title "Indexer" would be more appropriate, such devices are invariably known as dividing heads. Designs for that shown **in Photo 7** and a much more adaptable head are included in Chapters 7 and 8. In addition, many suppliers to the home workshop have designs and kits of parts for making dividing heads and rotary tables.



7. A basic home made dividing head

5. Dividing with no special equipment

Dividing with no, or very little, additional equipment can often be carried out and is worth considering even if the workshop is fully equipped with dividing facilities. It may be expected that such methods are limited to the simpler numbers, 3, 4, 6, etc. but as will be seen in the next Chapter much more complex numbers are possible, even those not available with a commercial dividing head.

Chapter 3

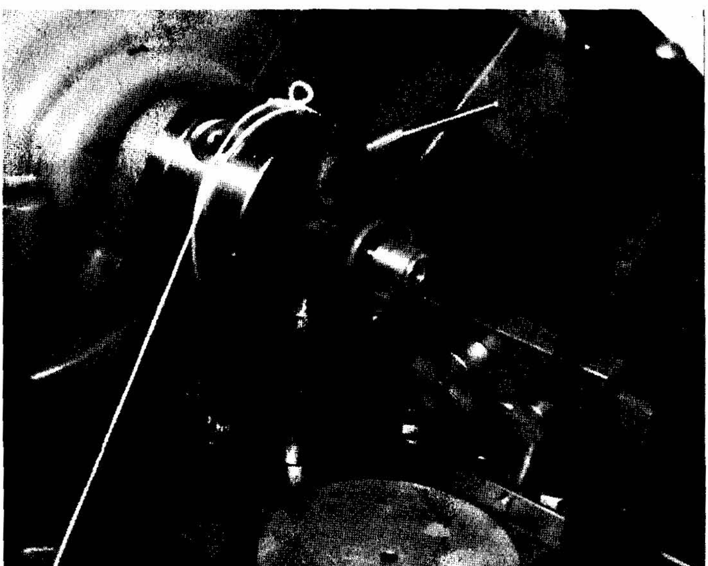
The Methods

Using Minimum Equipment.

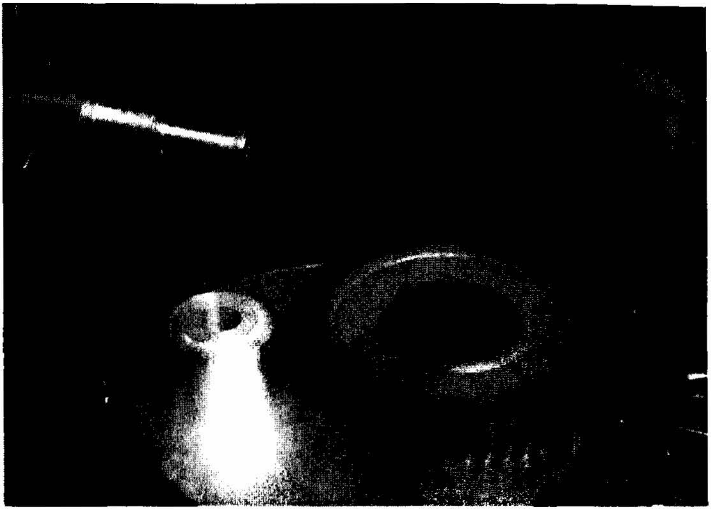
Having dealt with the equipment required in Chapter 2, it also mentioned that dividing can often be achieved with little or no special equipment. Whilst using a dividing head will in most cases be the ideal, other equipment is often used. The reasons for this can be varied, but will most often be because either a dividing head or the division required is not available or that the project is simple and more easily set up using some other method.

Using the lathe spindle

Typical of this would be when needing to make three divisions on an item in the



1. Using a gear on a stub mandrel to cut a dial.



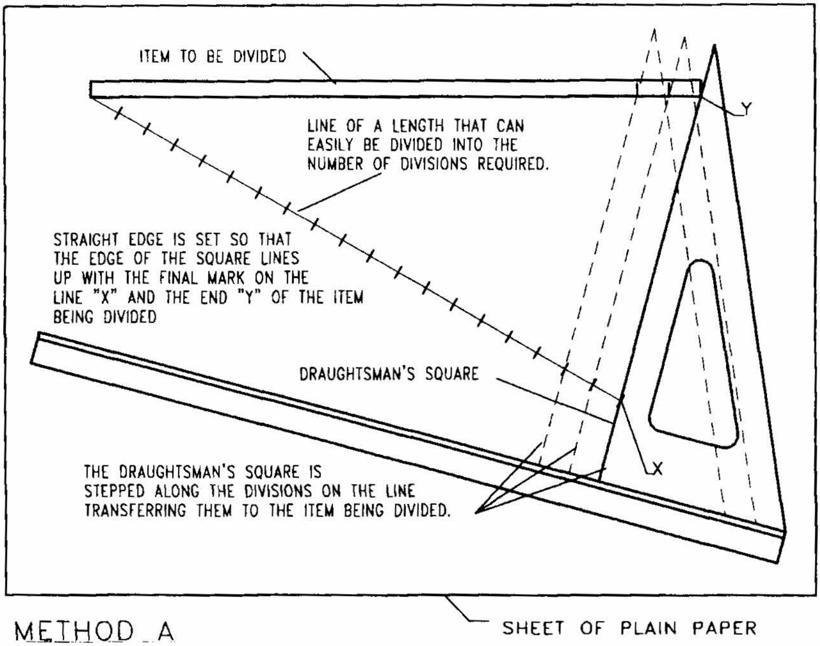
2. The dual-stub mandrel for mounting both gear and dial.

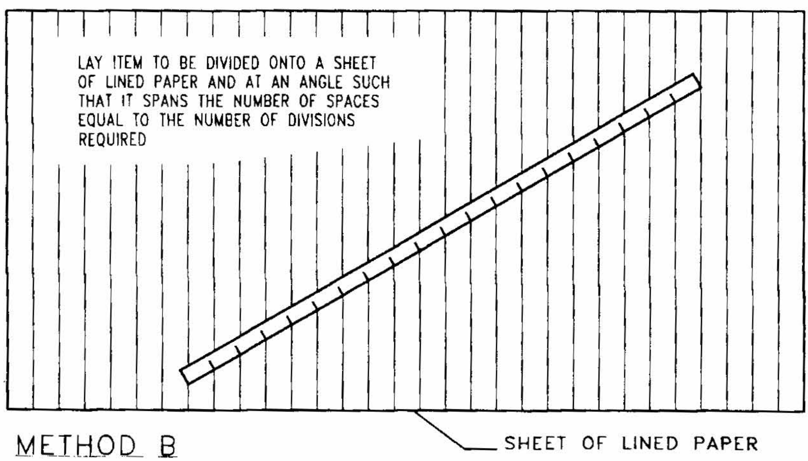
three jaw chuck. In this case, placing a piece of packing between the bed of the lathe and each chuck jaw in turn would be accurate enough for most applications and certainly much quicker than setting up a dividing head. Do not fall into the trap of thinking that just placing the packing under the jaw in the rear position will give you six divisions, this will only work if the height of the packing is exactly centre height minus half the jaw thickness.

An extension to this idea having the advantage of providing a wide range of divisions, is to include a gearwheel into the set up and use this in a similar way, **Photo 1**. Using a weight on the end of a piece of string attached to the chuck, as seen, will keep the short length of bar in place whilst the operation of cutting a dial is carried out. Both gear and dial being made are mounted on a dual taper stub mandrel as seen in **Photo 2**. Of course, you do not need to use every tooth space, if you required 15 divisions, a 45 tooth gear stopped at every third space would give the required result. Also, by careful choice of a thin piece of packing to place below the bar, or a slightly longer second bar, a 50 tooth gear could be used to calibrate a 100 division dial.

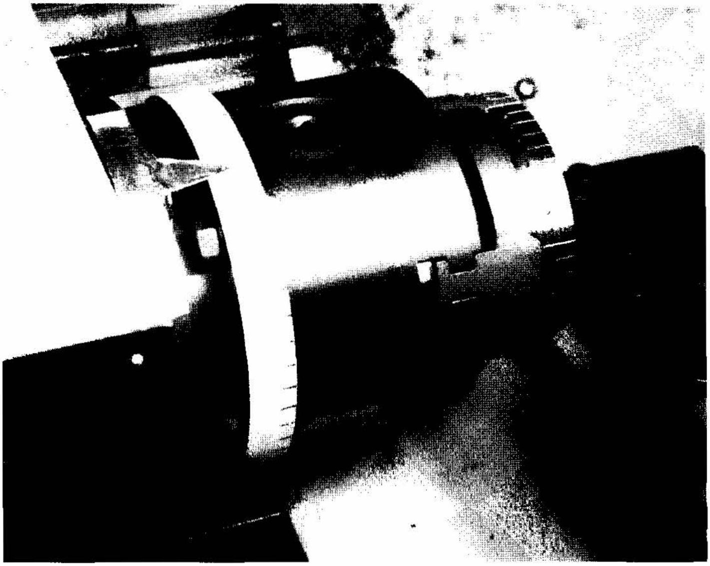
Another simple idea and only limited in the number of divisions by a practical maximum, is to wrap around the back plate, or face plate periphery, a strip of paper suitably marked with the divisions required. This may seem a simple idea but the space between each marking, when in the flat, is likely to be a complex value. Say with a 100mm diameter backplate the circumference would be 314.1593mm. Dividing this into any number would result in a value that would be difficult to work with, fortunately, there is a simple way out of the problem.

Wrap your strip of paper, a little on the long side, closely round the periphery of the chuck and carefully cut through both with a sharp knife at the overlap, you will now have your 314.1593mm strip of paper.





SK1 Dividing length

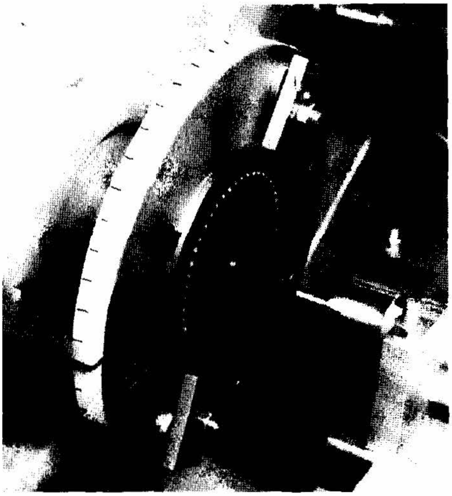


3. A divided paper strip around chuck's back plate for calibrating a dial is an easy and practical approach to the task.

Fix this down on a piece of paper and on this draw a line at an angle to the strip of paper and starting from one end of it. For example, say you wanted 19 divisions mark the line at 285mm (19 x 15) and mark this off at 15mm increments. Using a straight edge and a draughtsman's square as illustrated in **SK1A**, transfer the divisions to the strip of paper that will now be accurately divided. If you have a large sheet of lined or graph paper, then an alternative, and probably easier method is illustrated in **SK1B**. Fix the strip to the chuck and use this to achieve the required result. **Photo 3** shows a dial being cut in this way. As an afterthought I realised I could have marked the strip with the positions for the longer lines.

An ideal paper to use is an A4 sheet of adhesive paper as used in photocopiers or computer printers when making large adhesive label's and the like. If this is not long enough, cut two wider strips, peel back a short length of the backing paper on one and join together. To ensure the required strip is straight it can then be trimmed to the width required. Thoroughly clean the faceplate or chuck's backplate edge to ensure adhesion. The process in **SK1** is a rare occurrence in the workshop for dividing length.

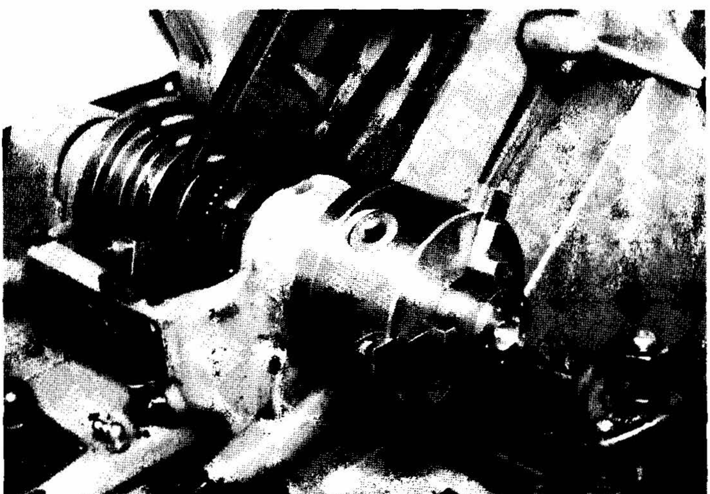
All the methods above have one major problem, there is no method of securely locking the spindle. With only a little care this should not present a problem for the tasks shown being undertaken. For more arduous tasks though, such as machining a hexagon on a turned item, it would be a non starter. Because of this, even though the system can easily cope with any number, it would not be suitable for cutting that gear for which you do not have a suitable dividing plate, there is though a simple way out.



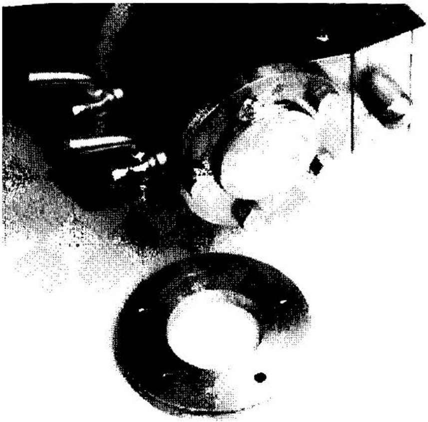
4. Making a division plate using a divided paper strip and drilling spindle.

Mount a disc onto the face plate and using a suitably divided paper strip round the faceplate's periphery will enable the disc to be marked out for making a dividing plate. The positions can be established using an automatic centre punch mounted on the top slide, or, if available, a small drilling spindle as in **Photo 4**. This process should make a dividing plate accurate enough for most applications. However, if eventually used via a worm/worm wheel, rather than direct, the improvement in accuracy this provides, as described in Chapter 4, would certainly make it adequate. Incidentally, the bar against which the faceplate markings are set uses the same two fixings as that for the bull wheel detent seen in Photo 1 in the Chapter 2.

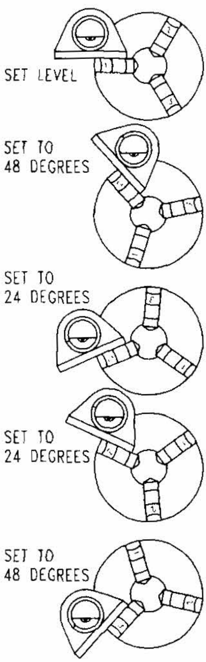
Should you be making a small stationary steam engine **(Photo 5)** the cylinder end flange requires 5 holes on a PCD. Positioning these prior to removing the flange from the lathe after initial machining could be done. However, I chose to make a small drilling jig (seen in **Photo 5**) for the purpose and using an automatic centre punch mounted on the top slide to mark out the positions and the lathe's bull



6. An auto centre punch on the top slide is being used to mark the five positions for the cylinder head drilling jig. The bull wheel is controlling the angle between divisions.



5. *The stationary steam engine requires 5 holes on a PCD.*



SK2 Creating 5 divisions

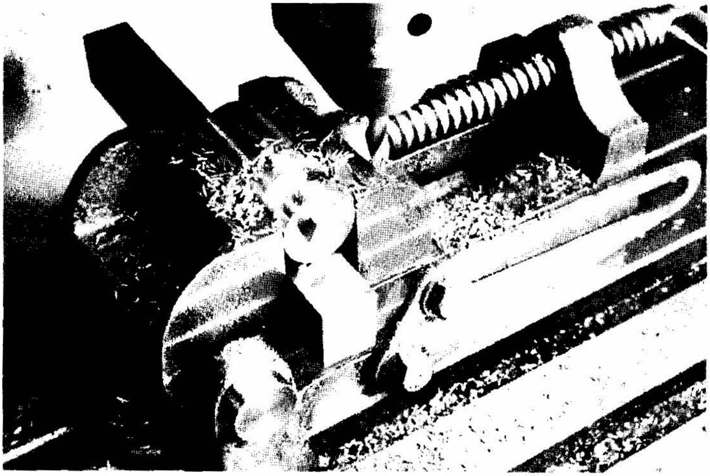
7. *This post requires that a hexagon is machined.*

wheel to set the divisions, **Photo 6**.

The following would have been an alternative approach to indexing the five divisions. Five holes on a PCD requires a rotation of 72deg. between each position. This can easily be achieved using the jaws of a three-jaw chuck and a combination-square protractor as illustrated in **SK2**. A plastic band, wrapped around the chuck and weighted, would provide some friction to aid setting and holding position. This system theoretically could be used for any number of divisions, its use is though only practicable for low numbers, even here it's not a first choice method but worth considering in some cases. Using the four-jaw chuck would be an advantage for some numbers.

On the milling machine.

The small post seen in **Photo 7** has a spanner hexagon that was machined as shown in **Photo 8**. A temporary hexagon

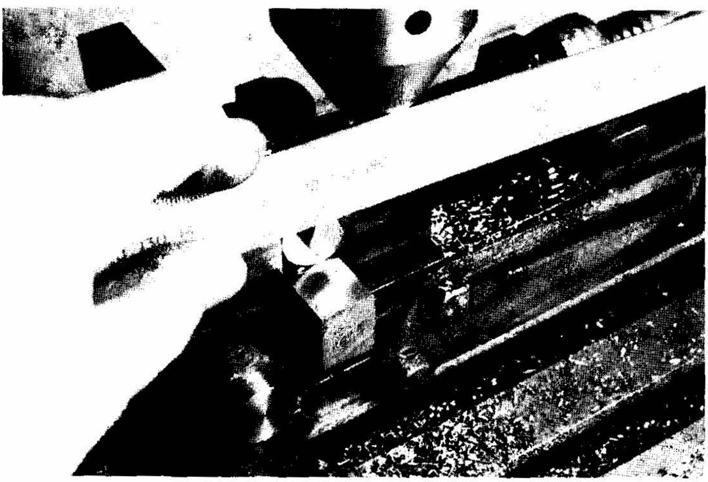


8. *Machining the hexagon.*

headed screw in the bottom is used to set it up for each facet as shown in **Photo 9**. Whilst this is not that precise, it is, if carried out with care, more than adequate for the purpose. Alternatively, it could be set using a square off the table surface setting one face of the screw head upright.

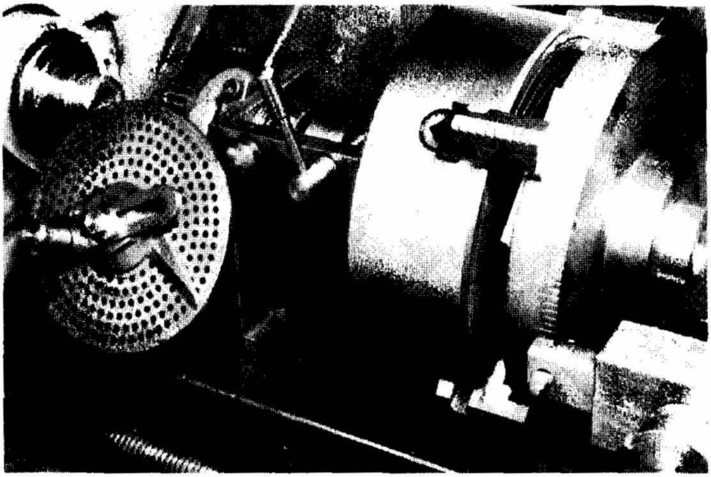
Using a rule and a square on the same workpiece would enable twelve divisions and if only every third position was used a square can be machined using a hex head screw.

The above illustrate just what can be done using the bare minimum of equipment, no doubt some readers will know of, or be able to devise, other methods.



9. *Setting each facet of the hexagon head screw level by eye using a steel rule.*

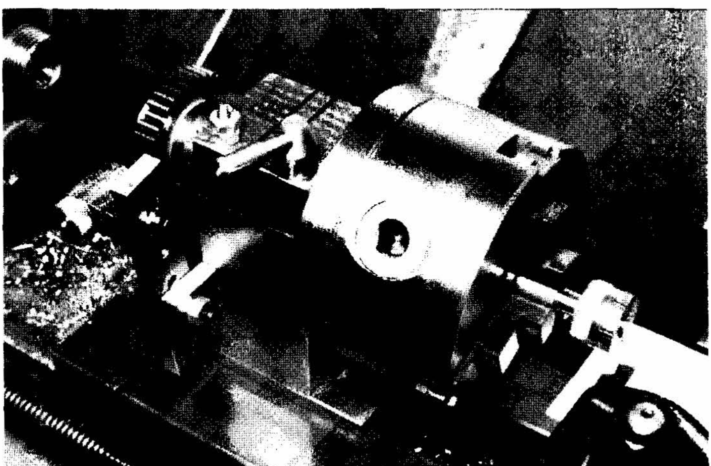
10. *Calibrating a rotary-table table with 360 divisions. Dividing head being used is that in Chapter 8.*



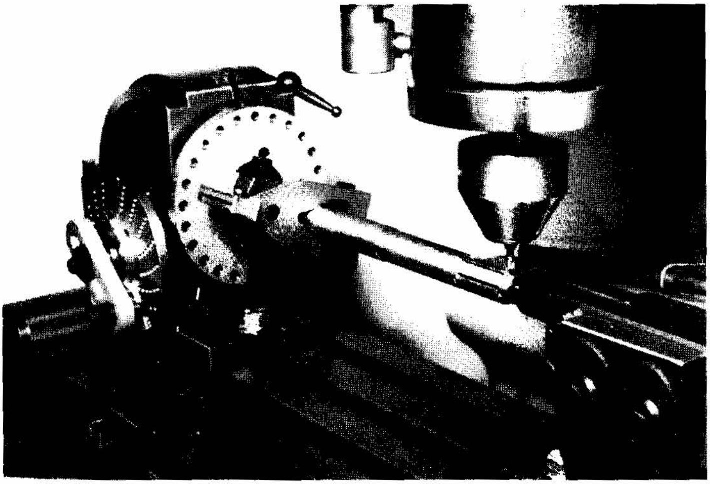
Using a dividing head.

Having determined which dividing plate to use and the number of holes to be traversed for each division (this to be described in Chapter 4) there is not much left to the exercise other than mounting the workpiece and carrying out the required machining operations. Anticipating that anyone arriving at this point in workshop activity will already have gained the skills of mounting and machining, there is therefore little that needs to be stated. I am though including a few photographs as examples.

Mounting the workpiece will normally be straightforward following closely similar



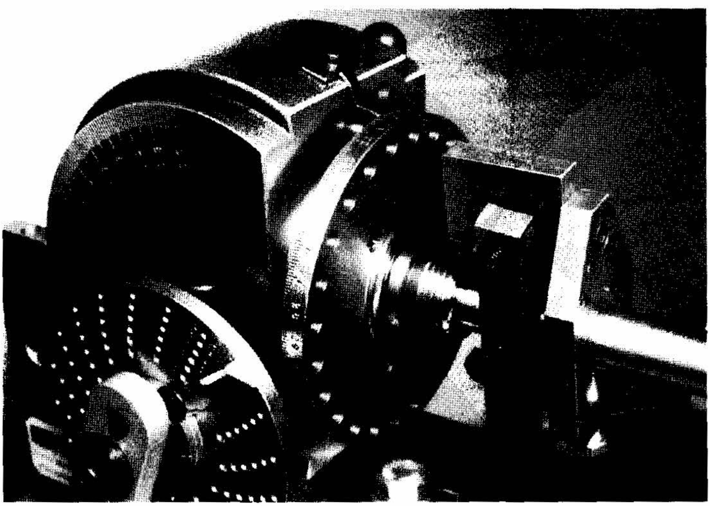
11. *Calibrating a dial whilst held on a stub mandrel. The dividing head being used is that in Chapter 7.*



12. Machining splines on a between centres shaft.

operations on the lathe. Frequently it will be to use the three or four jaw chuck either holding the part itself, **Photo 10** or using a stub mandrel as in **Photo 11**. In many cases the component being machined will have previously been turned on the lathe and to maintain concentricity it will be preferable to move it to the dividing head without removing the workpiece from the chuck. If a part has an irregular shape or is too large for the chuck the faceplate will have to be brought into use as it would on the lathe.

Mounting the workpiece between centres is another method of work holding

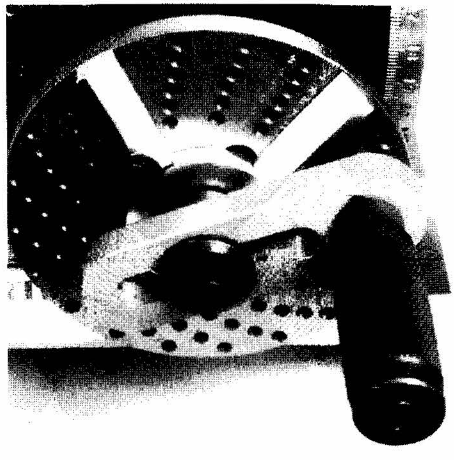


13. Showing the dividing head driver method for between centres work.

and is obviously used where the part to be machined is too long for either the chuck or the faceplate. **Photo 12** shows a long shaft having splines machined into one end. Whilst appearing to follow exactly the situation when mounting between centres on the lathe there is one important difference.

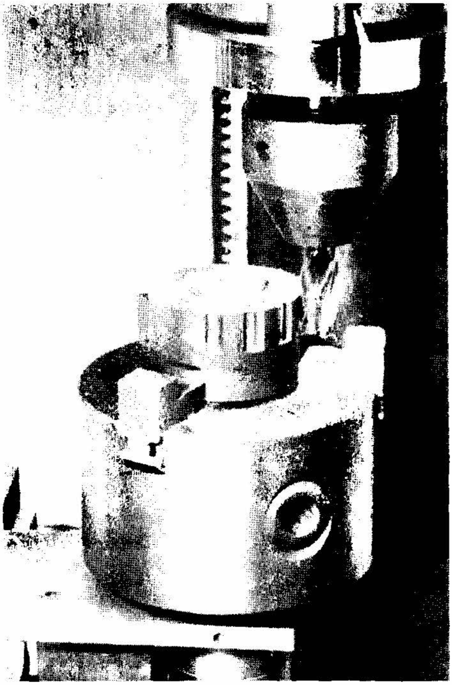
In the case of the lathe, the lathe carrier (sometimes known as a lathe dog) mounted on the component will be driven by the driving peg mounted on the catchplate. The carrier and peg will often be held together with a loop or two of string or wire but relying largely on the machining force to keep them in contact. This will not suffice when using the set-up with a dividing head as the machining will not necessarily keep the driver and driven together. Because of this the driver differs from the lathe catchplate with driving peg and enables the driver and driven to be rigidly coupled, **Photo 13** shows the method. See also Photo 2 in Chapter 1 for an illustration of the dividing head's driver. Lathe carriers with bent arms are available but the position of the arm would depend on the diameter of the workpiece. Unfortunately, I have not found a commercial carrier that overcomes this problem, though they may be around. I have therefore developed my own design seen in the photograph and which features in Chapter 6.

Having arrived at the point where the component is ready to be machined and armed with the correct dividing plate and the number of holes to be traversed, machining can commence. Taking as an example the need for 14 divisions using a dividing head having a 40:1 worm/worm wheel ratio. Typically, this will use a dividing plate having 49 holes and be achieved by traversing 140 holes, or in other terms, two turns plus 42 holes per division. The mathematics of this being $40 \times 49/14 = 140$. It will be obvious that whilst two turns will be easy, counting the additional 42 holes at each division will be prone to error.



14. Close up of dividing plate fingers.

Because of this, dividing heads are fitted with adjustable fingers, **Photo 14**, which are set to the number of holes between one division and the next. These hold their angular setting whilst still enabling them to be rotated as a pair between each division. The construction has some inbuilt friction that enables the fingers to be rotated as a pair whilst being sufficient to ensure they remain in position during each machining operation. Mostly, fingers and input rotate in the same direction but due to an upper limit to the number of holes that the finger can span, typically around 75% of the number of holes in the ring, for larger numbers of holes they rotate in opposite directions. **SK3** should make the situation clear.



15. Machining with a vertical dividing head will result in the cutter attempting to unscrew the chuck. Very light cuts are therefor essential.

If using a shop made dividing head with a gear to replace the dividing plate, then the facility of adjustable fingers to determine each division is not likely to be included. This statement based on the designs I have seen, including those in this book. However, I can see no reason why such a facility cannot be built into such designs. Without this it will be a case of counting the number of teeth traversed with considerable care. It is frequently the case though that the division is achieved with one revolution of the gear, such as every third tooth when using a 45 tooth gear for 15 divisions. Where this is the case the gear can be marked appropriately prior to fitting it onto the dividing head. A coloured chinagraph pencil is excellent for this. The bull wheel in **Photo 6** has been marked in this way and may be visible if the final printing permits it.

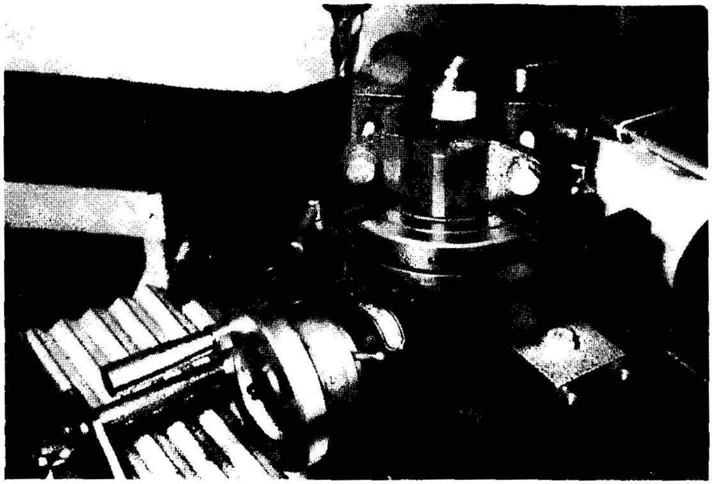
Having said that in terms of the machining operation there is no difference between normal milling operations and those using a dividing head, there is one potential disaster area. **Photo 15** shows a handwheel being made by machining notches around its edge. Careful observation of the set-up reveals that the cutting action will be attempting to unscrew the chuck from its mounting. It is essential therefore that the chuck is very firmly screwed on and that only very light cuts are taken. Should the chuck become free, then there will certainly be a spoiled component and probably a broken cutter also. Do be aware of this and take great care when working in the vertical mode. It can also occur in the horizontal mode is some specialised situations.

Using the rotary table.

If you have a fully equipped rotary table, that is with dividing plates and tailstock, then the above explanations will largely apply with only some small changes regarding workpiece mounting.

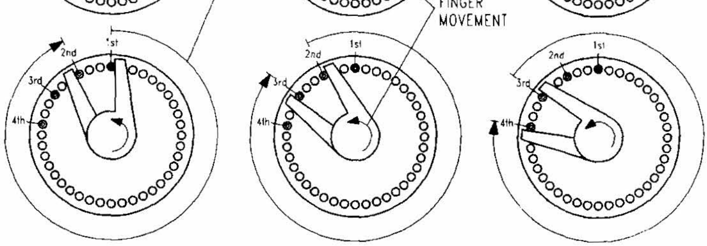
If however, as is most likely, you have just the basic rotary table you will be faced with setting the divisions by using the micrometer dials at the hand wheel. Consider using a table with a 60:1 ratio worm/worm wheel and 60 divisions on the dial giving 0.1deg. rotation per division. If we now consider, as above, a requirement for 14 divisions this will require and output

16. Machining a hexagon for a large nut using a rotary table.

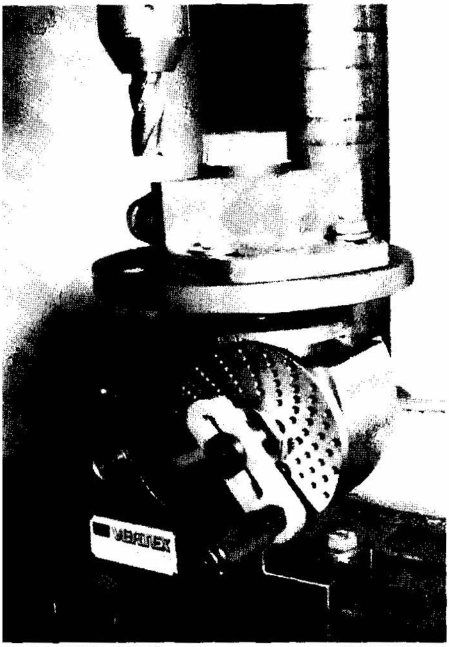


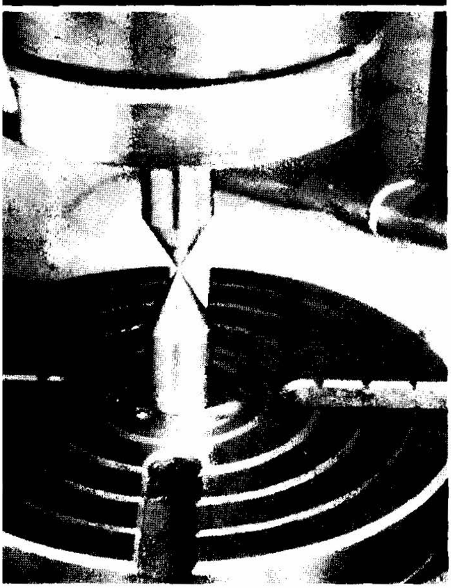
of 360/14 degrees per division, that is 25.7143 degrees. This equates to 257.143 divisions, or 4 turns plus 17 and a little bit (0.143) divisions, it is the little bit that is the problem. If the task is to place 14 holes on a PCD for bolting two flanges together then a little clearance in the bolt holes should make the approach possible. Do not though simplify the figure to 25.7 degrees as the error of 0.0143 will accumulate over the 14

SK3 USING THE DIVIDING PLATE FINGERS



It is normal for dividing fingers and the input arm to move in the same direction. However, due to a upper limit that the dividing fingers can span, around 75% of the maximum, for larger spans rotation of the fingers is opposite to that of the input arm as shown above.





17. Attempting the task in photo 16 but using a dividing head in the vertical mode requires a lot of head room. It is though a non starter, see comment for Photo 15.
18. Aligning centres in preparation for positioning workpiece.

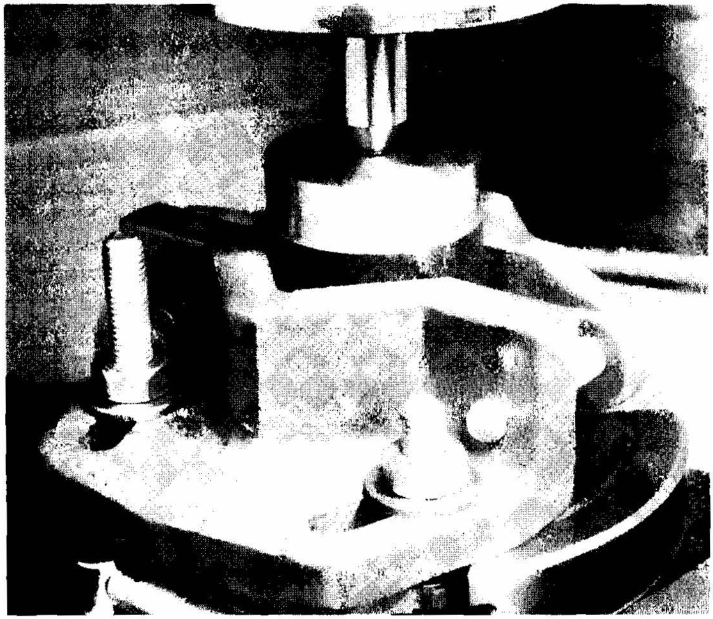
divisions making the last have an appreciable error. Do though work out a figure for each division, say 257.143, 514.286, 771.429, etc.

From this, work out the turns and divisions, 1st div, 4 turns + 17.143, 2nd div, 8 turns + 34.286, 3rd div, 12 turns + 51.429, etc. Whilst this is possible, it has to be asked is it practicable having to carefully set up each position? For the example given, probably just, but whether you wish to count and set up each position in this way will be a personal choice. If gears are to be cut or a greater number of divisions are to be made I doubt if it is practicable and it will be a case of equipping you rotary table with dividing plates or obtaining a dividing head of some form.

Some dividing applications are though equally, or more appropriate, for the rotary table. **Photo 16** shows a hexagon being made for a large nut. The material would have been too large to be held securely in the three-jaw chuck mounted on the dividing head and so the rotary table with Keats angle plate was brought into use. The rotary table therefore coped with the situation admirably and requiring only six divisions the table's dials were adequate for setting each position.

Using a dividing head in its vertical mode and fitted with a faceplate for the task, **Photo 17**, would seem possible but it has some severe limitations. Available height in the machine and rigidity of the assembly,

19. *Positioning workpiece by this method should be accurate enough for almost all applications.*



especially the light nature of the faceplate are both likely problem areas. However, as mentioned earlier in the chapter, in this mode rotation of the cutter is endeavouring to unscrew the faceplate. It is not therefore a practical proposition and should not be attempted, even with a light cut!.

Mounting a workpiece onto the rotary table, typically as in **Photo 16**, is not as simple as first envisaged as it must be concentric with the table. To do this mark the workpiece with a centre punch mark, or centre drill. Then, place a centre in both the rotary table and the machine spindle and align them as in **Photo 18** using the machine's X and Y movements. Place the workpiece onto the table and line it up using the machine's centre and clamp in position, **Photo 19**. This should be accurate enough for all but the most demanding situation, in this case final positioning can be set aided by a dial test indicator and rotating the rotary table.

Dealing with backlash

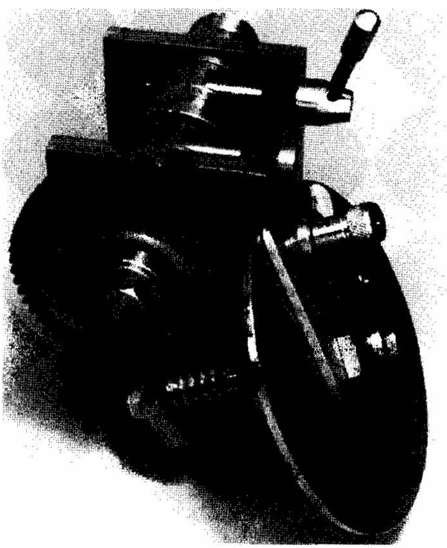
Depending on the equipment being used there may be appreciable backlash in the assembly, but even with the more precision items it will not be totally absent. In all cases, it is advisable to take up backlash manually by attempting to rotate the workpiece in the same direction at each division prior to locking the spindle ready for machining. In some cases a length of string wrapped around the chuck, workpiece, etc. and weighted will perform the task automatically for you.

Chapter 4

The Mathematics

Before one gets down to producing the workpiece it will be necessary to establish the set-up required. The process is more complex than many will envisage, but fortunately the mathematics itself is relatively simple.

The two central values when carrying out the required calculations are the worm/worm wheel ratio and the number of holes on the dividing plate ring being used. In the case of a rotary table not fitted with a dividing plate then the number of calibrations on the hand wheel dial will be the important factor.



For commercial dividing heads 40 :1 seems to be by far the most common, but in the case of rotary tables there is more variation, 40, 60 and 90:1 all being frequently available.

Dividing plates by nature of their construction have more variation with smaller plates having around 6 rings of holes and larger ones 16 rings, maybe more in some cases. The smaller plates may have a maximum number of holes of 50 whilst the larger plates may have up to 100 holes. A smaller head is likely to be supplied with three plates making 18 rings in all, a larger head will probably have 2 plates with 16 holes making 32 rings in total.

Another factor is that dividing heads from different sources may be provided with plates having differing numbers of holes in each ring, additional plates also being available to fill some of the gaps. This all

1. Shop made dividing head having the ability to be used with differing worm/worm wheel ratios.

adds up to considerable variation in what is available and increases the number of permutations, making it impractical to publish in this book tables covering every possibility.

Because of this and not having access to tables covering a wide range of situations, I firstly decided not include any tables at all. However, I felt this was unfortunate and have as a result developed a computer program to provide me with any combination possible. From this I have chosen to provide tables for plates having rings with 15, 16, 17, 18, 19, 20, 21, 23, 27, 29, 31, 33, 37, 39, 41, 43, 47 and 49 holes. These appear to be very common combinations. Values have been worked out using these and three worm/worm wheel ratios 40:1; 60:1 and 90:1. Having provided these lists they will be of particular benefit to those who make their own dividing heads. The lists can be found in Chapter 11.

If purchasing a new commercial dividing head it will of course be supplied with tables for the dividing plates included, but will not cover any additional plates you make or purchase later to fill in some of the missing divisions. A secondhand head may also be missing its manual. It is worth repeating here that only the much more expensive universal dividing head will be able to provide all divisions, at least up to 380. A semi universal head will likely be provided with dividing plates that will give all numbers up to 50 with progressively fewer the higher the number, typically 29 between 51 and 100 but only 12 between 300 and 380.

Some divisions considered

To make the initial explanations as simple as possible I have chosen to base these on a combination of 60:1 for the worm/worm wheel ratio and 60 holes in the dividing plate ring being used.

Consider creating a dial having 125 divisions for use with an eight threads per inch (TPI) leadscrew requiring an angle between divisions of 2.88 degrees (360/125 = 2.88). With the dividing head having a 60:1 worm and worm wheel ratio and fitted with a 60 hole dividing plate the rotation will be 0.1 degree per hole movement. If we consider 29 holes giving 2.9 degrees per division a small error of plus 0.02 degrees will result. As the error will be accumulative a final division of only 0. 4 degrees would result, obviously far too great. Had the error been very much smaller then just possibly it may have been possible to live with it.

Taking now the requirement for a 127 tooth gear, as used in an imperial to metric conversion on the changewheels for an imperial lathe. In this case the required angle between each division is 2.8346456. Using 28 holes on the division plate would be the nearest but as a gear is being produced any error at all will be unacceptable.

Other divisions will though be much simpler. One hundred divisions, as required on a dial for a 10 TPI leadscrew, would require 3.6 degrees per division, easily being accommodated by 36 holes on the sixty hole division plate.

How many holes?

The above examples serve to show that it is necessary to choose a dividing plate that will enable a requirement to be achieved exactly.

Let us further consider the 60:1 ratio

worm with a 60 hole plate. To rotate the output of the dividing head one full revolution the worm will need to rotate 60 times. As the plate has 60 holes this will result in the setting device passing 60 x 60 holes, that is 3600. Any whole number that divides exactly into this is an achievable division. Taking an easy example, say 40 divisions, this will require the setting device to pass 3600/40 holes per division, that is 80 holes, being one full turn plus 20 holes.

Whilst 3600 is a relatively large number, the number of possible divisions is quite small and are all what one might call simple numbers. These are 2, 3, 4, 5, 6, 8, 10, 12, 15, 18, 20, 24, 30, 36, 40, 45, 50, 60, 72, 80, 90, 100, 120, 150, 180, 200, 240, 300, 360, 450, 600, 720, 800, 1200, 1800 and 3600.

Knowing the dividing head ratio together with the number of holes on the dividing plate it will be easy to determine if the division required is achievable. However, you are likely to have a set of dividing plates (or gears) that could result in a lot of calculations, although simple, until a suitable dividing plate is found, or maybe not found.

On some occasions, your requirement may not be covered by the published charts, or you may not have all the plates quoted but have others. In this case you will have to resort to calculation. The essential requirement is that the dividing head ratio (R) times the number of holes on the plate (H) divided by the number of divisions required (D) must be a whole number (W), that is

$$W = \frac{R \times H}{D}$$

This is a simple calculation if one has R, H and D but what if attempting to work out the number of holes (H) required on the dividing plate for a given division (D). In this case there are two unknowns (The whole number, W and the number of holes, H) making the process to appear less than straight forward. However, the value for W can be any number providing it is whole.

Consider the requirement for 57 divisions in which the formula will read.

$$W = \frac{60 \times H}{57}$$

The values for R and D, 60 and 57 in this example, should be simplified to their smallest values, that is by dividing both by 3, giving.

$$W = \frac{20 \times H}{19}$$

From this it can be seen that W will be whole providing H is 19 or any multiple of this, 19, 38, 57, 76, etc.

Having established the dividing plate to be used it will be necessary to calculate the number of holes traversed for one division. Assuming a plate having 38 holes is chosen, the number of holes for a complete revolution of the workpiece will be.

$$60 \times 38 = 2280$$

The number of holes traversed per division will therefore be.

$$\frac{2280}{57} = 40$$

Forty being achieved by one complete turn (38 holes) plus 2 holes.

Whilst 60 is a common ratio, 40 and 90 are also common, (40 very common for commercial dividing heads).

Use for a dividing head in the home

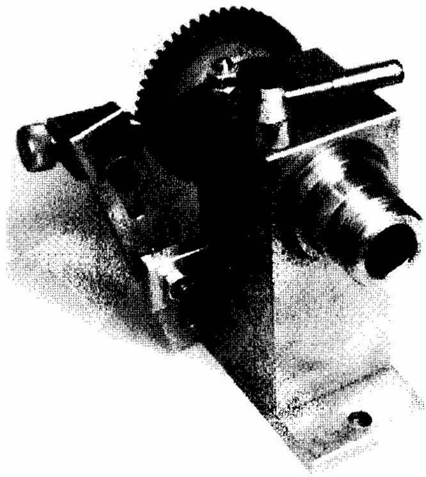
workshop is likely to be limited and because of this purchasing an expensive commercial item may be difficult to justify. Because of this the workshop owner may choose to make one. Others may go down this route finding the manufacture of a dividing head an interesting project in itself. One aspect of dividing heads made in the home workshop is that they may not have the restrictions inherent in those made commercially.

The dividing head seen in **Photo 1** is not limited to a single worm/worm wheel ratio as the design can cope with differing diameter gears. Ratios of 30:1, 35:1, etc. are therefore obtainable. The simpler head, essentially an indexer, shown in **Photo 2** can have additional gears added as in **Photo 3**. This opens up possibilities that are not available with a commercial unit.

The additional gears in **Photo 3** amount to a reduction in angular movement between the dividing device (a gear in this case) and the dividing head spindle in the same way as a worm and worm wheel. However, the ratio with a worm and worm wheel will always be a simple one 40:1, 60:1, etc. With two spur gears though the result may be complex. Typically, gears of 60 and 20 teeth will have a ratio of 3:1 but gears of 45 and 25 teeth will have a ratio 9:5. Whether this is usable will depend on the number of positions on the dividing device.

The following should give an indication as to what is possible. One important point to make is not to work out the values in decimal terms as this can so easily shroud the meaning of the answer, do stick to fractional form.

When calculating the results for a dividing head, typically as seen in **Photo**



2. Simple single gear dividing head, also made in the workshop.

3, the formula given on page 34, will still apply. However, if a ratio of 9:5 is being used this will go into the formula as 9/5 and would read.

$$W = \frac{9 \times H}{5 \times D}$$

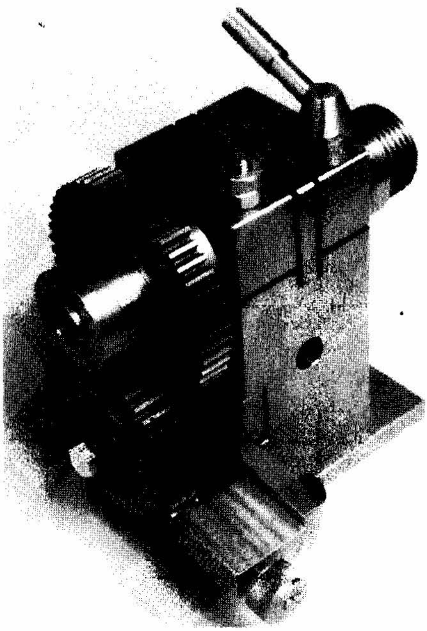
Considering a requirement for 63 divisions it will read

$$W = \frac{9 \times H}{5 \times 63}$$

Simplifying this by dividing 9 and 63 by 9 gives

$$W = \frac{1 \times H}{5 \times 7}$$

Five times seven being 35, W will therefore be whole if H = 35 or 70, both standard change wheel sizes. Incidentally, 63 is a value not achievable with my 40 :1 commercial semi-universal dividing head or



my 90:1 rotary table. 63 is frequently suggested as a good change wheel to use in place of 127 tooth wheel, being smaller, when cutting metric threads on an imperial lathe.

Some More Examples

Example 1

Consider a set up with a 30 tooth dividing gear and a 60/20 tooth gear chain, that is 3:1. The formula is therefore number of holes passed for 1 rotation of the dividing head output is 30 x (60/20) = 90 holes. This will enable the 30 tooth wheel to give divisions of 2, 3, 5, 6, 9, 10, 15, 18, 30, 45 and 90. Nine, 18, 45 and 90 being additional to those which would be possible with the 30 tooth gear direct.

Example 2

Consider a set up with a 50 tooth dividing gear and a 75/30 tooth gear chain that is 15:6

3. Two additional gears fitted to the head seen in Photo 2 *giving a greater range of possible divisions.*

The number of holes passed for one complete turn of the dividing head output is therefore 50x(75/30) = 125 holes. The point to note here is that even though the ratio is 15:6 it still results in a whole number for the number of holes. Available divisions are only 5, 25 and 125, but 125 is useful for calibrating a dial for an 8 TPI (threads per inch) leadscrew. Again this is not available with my commercial dividing head or rotary table.

Example 3

For this example I am suggesting a set up with a 40 tooth dividing gear and a 50/30 tooth gear chain, ratio 5:3, number of holes passed for one complete turn of the dividing head output is therefore 40 x(5/3) = 66-2/3 holes, (note we work in fractions). With an answer of 66-2/3 holes the set-up would appear to be worthless, as no number will divide into this. If however in this case the output is allowed to rotate a further two turns then this results in 200 holes passed.

This will give a range of divisions but most obtainable by easier gear combinations. However, 200 will be useful if calibrating a dial in half thou's for a ten TPI leadscrew.

With the workpiece (dividing head output) rotating three times it will be found that the divisions made on the second and third rotation fall as required between those made on the first rotation. I was inclined to prove this mathematically but feel that this may be overcomplicating the explanations. It will though work wherever a fraction of a division occurs with a single output rotation.

Example 4

As a more extreme example, a combination of a 40 tooth dividing gear and a pair of gears comprising 45 and 35 giving a 9:7 ratio and 51-3/7 holes. Seven complete turns will therefore give 51-3/7 x 7 which equals 360 holes passed. It can therefore be used when calibrating a rotary table in degrees.

These examples, which show only a minute fraction of those possible, do, I hope, give an indication of the range of possibilities with this set up, and as a result enables you to go down this avenue knowing that it is possible.

For the sake of simplicity I have ignored the effect of using a forked detent and for consistency with other explanations, have referred to holes when using gears as the dividing device; the slot between two adjacent teeth will of course be used. I have also used for my explanations, changewheels having increments of 5 between sizes, 25, 30, 35, etc. I do realise that a few lathes will use other increments, typically by fours. Whilst the results will be different the methods will still apply.

Further details

Chapter 7 includes a design for a simple, three gear dividing head and further details regarding the mathematics of using such a device. A list of divisions possible is also included in Chapter 11 based on a set of change wheels of 20 to 75 by five's.

Division plate errors minimised

Whilst not a calculation that the reader will be called to carry out, the following illustrates how a worm and worm wheel configuration (or two spur gears in a gear chain) reduces the effect of any division plate errors. The extent will no doubt come as a surprise to the uninitiated.

Consider a division plate with 18 holes theoretically spaced at 20 degrees (360/18 = 20), but having an error of 1 degree on the 12th hole, that is spaced at 19 and 21 degrees between its adjacent holes. If now attempting 9 divisions (40 degree spacing) and using a dividing head with a 60:1 ratio, the arm on the dividing head will have to pass 120 holes per division, that is 60 x 18 / 9. This is 6 complete rotations plus 12 holes ((6 x 18) + 12 = 120) for the first division.

In this example, input rotation will therefor be, (6 x 360) + (11 x 20) + (1 x 19) degrees, that is 2399 degrees for the first division, and for the next division, (6 x 360) + (11 x 20) + (1 x 21) degrees, that is 2401 degrees. As the worm/worm wheel arrangement reduces the rotation by a factor of 60 the angles at the workpiece will be 39.984 degrees (2399/60) and 40.016 degrees (2401/60). From this it can be seen that the second division will be accurately placed as it compensates for the error in the first, (39.984 + 40.016 = 80) but the +/-1 degree error between the two on the division plate has been reduced to 0.016 degree, 1/60th that on the dividing plate. The value of 1/60th is no coincidence but will always be by the same factor as worm/worm wheel ratio.

A feature of this is that even plates made in the home workshop by relatively inaccurate methods will still produce results accurate enough for all but the most demanding requirements. Even here you can use the dividing head to make a second plate and use this for producing the final product. By this means you will benefit from improved accuracy twice over.

Chapter 5

Co-ordinate Calculating 1

Holes on a Pitch Circle Diameter (PCD)

The mathematical method.

The need to place holes on a PCD can occur for many different reasons but most often only involving a small number of holes, typically 3 or 4 when drilling a back plate to take a chuck. In modelling engineering 5 or 6 holes to fix the cylinder cover on a stationary steam engine maybe.

The obvious first choice for positioning the holes will be either a dividing head or rotary table. However, some workshops will not be equipped with either of these and even if they are they may not adequately support the workpiece, either due to its size, weight or shape. Also, even if a semi universal dividing head is available many numbers over 50 will not be achievable. Situations will therefore arise where an alternative method has to be found. Probably the most likely requirement where a larger number of holes are required will be to make a division plate, required, but not presently available in the workshop.

One of the commonest alternatives will be when the requirement is for six holes. This will be to set the dividers to the radius, scribe a circle and then with the scriber still at the same setting step round the scribed circle. Many applications will though be much more difficult than that and another method will be needed.

One such method is to work out the position of each hole in terms of its X and Y co-ordinates and uses the milling machine leadscrew dials to position each hole. The advantage of this method is that it achieves a high degree of accuracy, also any number of divisions is achievable, except of course for a practical maximum. Before this can be undertaken the positions of the holes need to be calculated. **SK.1** shows a very simple example requiring to position 5 holes on a given diameter.

The Formulae

The formula for the X co-ordinates is

$$X = R \text{ Cos} \frac{(P - 1) \times 360}{N}$$

where R equals the radius (that is PCD/2) P equals the hole number, e.g. 1, 2, 3, 4 or 5 and N equals the number of holes, 5 in this case. Similarly for the Y co-ordinates

$$Y = R \sin \frac{(P - 1) \times 360}{N}$$

Calculating these values, even when there are many more holes, will not be that arduous if you have a calculator having trigonometrical functions. Unlike printed tables that normally list values up to 90 degrees a calculator will deal easily with the angles above 90deg., giving the value and whether it is positive or negative. I would suggest therefore that a basic scientific calculator should be a standard item in the home workshop. Even better would be to obtain a programmable calculator, in this case just enter the formula once, then enter sequentially the variables (P only in this example) to arrive at each required value.

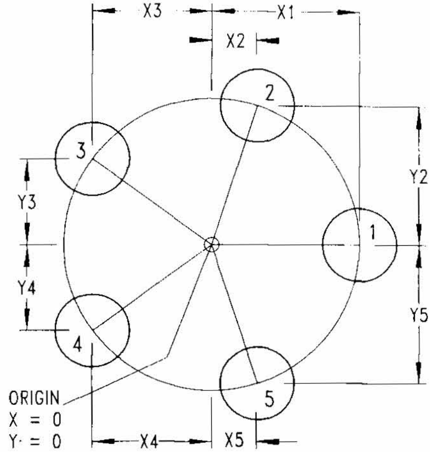
A disadvantage of the method in **SK.1** is that it involves both positive and negative co-ordinates making it somewhat difficult to equate the values to those to be read off the leadscrew dials. This can easily be overcome by changing the reference point from the centre of the circle to a point equal to the extreme upper and left positions as in **SK.2** making all co-ordinates positive. The required co-ordinates are easily arrived at for X by adding the radius of the PCD to each value the formula for this reads:

$$X = R \cos + \frac{(P - 1) \times 360}{N} + \frac{PCD}{2}$$

For Y however the value arrived at must be taken from the radius of the PCD, the formula therefore reads:

$$Y = \frac{PCD}{2} - R \sin \frac{(P - 1) \times 360}{N}$$

Do take note that the value for R Sin ((P-1) x 360/N) for some hole positions will be a



FIVE CIRCLES ON A PITCH CIRCLE DIAMETER
ORIGIN AT CENTRE OF PITCH CIRCLE DIAMETER.

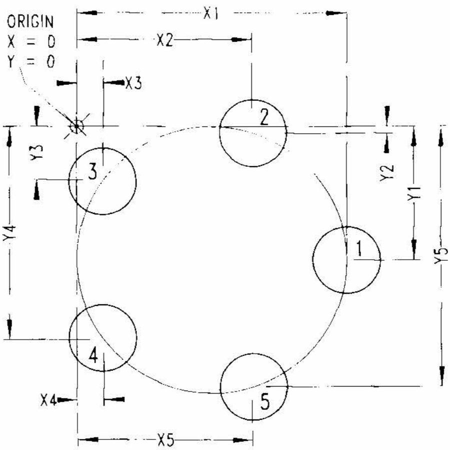
SK1

negative value creating a minus minus situation, mathematically this equates to a plus situation. In simple terms 5 - (-3) = 5 + 3 = 8.

Some may say that holes below the upper line should be negative if normal geometric conventions are applied. This may be correct but my comments relate to increasing values being read on the leadscrew dials. A drill placed over the zero line will move towards the lower holes when the hand wheel is rotated clockwise and the reading on the dial increases. However, some milling machines do not conform to this standard and the datum point will have to be other than in the top left as in SK2. It will not though alter the calculated values, only how they are applied.

Hole generation

A variation is often used in the home workshop to enable large holes to be cut in



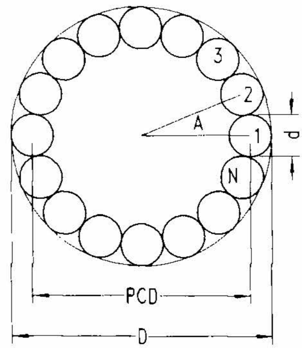
FIVE CIRCLES ON A PITCH CIRCLE DIAMETER
ORIGIN AT EXTREMES OF PITCH CIRCLE DIAMETER.

SK2

a workpiece by drilling touching holes on a pitch circle as illustrated in SK3. Whilst this can be done using relatively inaccurate methods it almost certainly will result in the need for more manual activity - filing, sawing, etc.

In this case the PCD is not of importance, what is, is the diameter on the outer edge of the drilled holes. The closer this is to the ultimate hole size will considerably minimise the finishing work necessary. What is required is, that with the chosen hole size and on the calculated PCD, that the outer edge is close to the hole size being made. This may seem relatively straightforward but the drill size and PCD have to be chosen more carefully and involves some calculation. Having started on the project I had anticipated that this may prove quite complex but in fact it is not that difficult. All that is necessary is to roughly estimate the number of holes to be drilled. However, do make the number divisible by 4 as this will make the holes identically positioned in each 90deg. segment and as a result reduces the amount of calculation required appreciably.

Having decided on the number of holes work out the angle (A) between each adjacent hole, that is 360/N where N is the number of holes. Chose an outer diameter (D) just sufficient for final finishing. The drill diameter (d) can now be calculated using the formula in **SK3**. If the drill works out too small, or too large, then reduce or increase



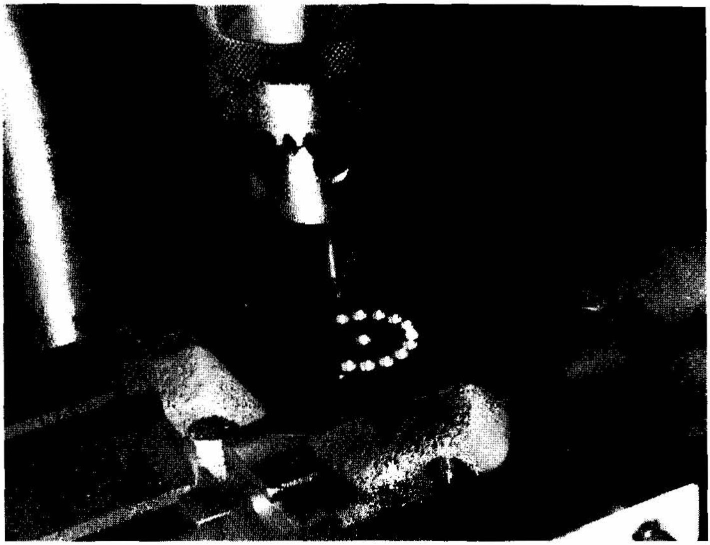
A ANGLE BETWEEN THE HOLES
N NUMBER OF HOLES
D OUTER DIAMETER
d DRILL DIAMETER
PCD PCD ON WHICH HOLES ARE TO BE DRILLED

$$A = \frac{360}{N}$$

$$d = \frac{D}{\dfrac{1}{\sin\dfrac{A}{2}} + 1}$$

SK3

1. *Using X and Y co-ordinates to mark out position of holes to remove the centre of a rotary table body. This to take the table's bearing.*



the number of holes estimated and recalculate. The PCD on which the holes are to be drilled will be equal to D - d. The co-ordinates can now be calculated as in the first example and then drilled.

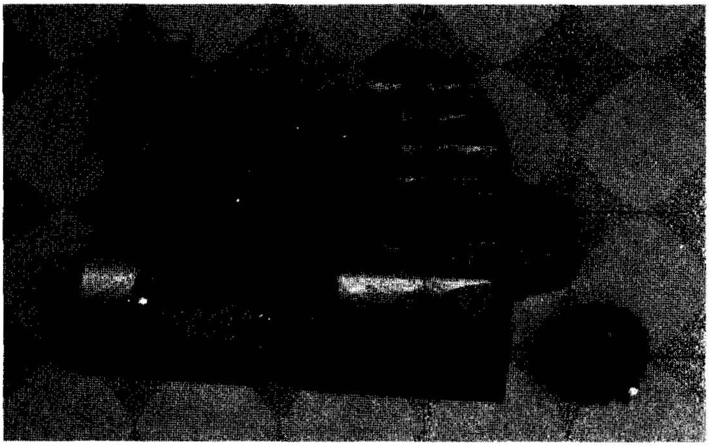
I used this process when needing to produce a large hole in a casting. **Photo 1** shows the hole positions being initially marked out. After drilling it was very gratifying when the centre just dropped away as the last hole was drilled, **Photo 2**. This made the care taken well worth the effort involved.

When adopting the above approach it is likely that in many cases the angle between each hole will be a complex value, it will though be of no consequence if the procedure is adopted fully. However, if the number of holes is chosen to arrive at a whole number for the angle, (say for 36 holes, 360/36 = 10 degrees), then a rotary table could be used if available as the limited calibrations on a basic rotary table will easily cope with such angles. In this case all that will be needed is to calculate the hole diameter and the PCD.

Using a computer

Having suggested using a programmable calculator, even better would be to use a computer spreadsheet program. This will not only produce the complete list of values on screen but will also enable a printout to be made for use in the workshop. If you are an accomplished user of spreadsheets you will not need me to inform you of the advantages of using these for repetitive calculations. If though you have a computer that you ably use for other applications may I encourage you to get to grips with spreadsheet applications.

A spreadsheet is basically a form divided into columns and rows and at each point where they cross a block is created, called a cell. Columns being referenced A, B, C, D, etc., and Rows numbered 1, 2, 3,



2. The centre fell away as the final hole was drilled, a very satisfactory conclusion!

4, etc. Typically therefore a cell in column C and row 5 will be referenced C5.

Each cell is established for a single purpose being chosen from four available uses.

1. To carry text entered at the spreadsheet design stage and used for such purposes as a heading for the sheet as a whole or headings for individual columns.
2. To carry text entered when the spreadsheet is used. In a financial application this could be the description of an item purchase.
3. To receive numerical data as the sheet is being used. Again in a financial application this could be the value of an item purchased.
4. To display numerical values calculated by the spreadsheet using the values entered as in 3 and using formulae entered by the sheet designer at the spreadsheet design stage.

There can be many entry cells and formulae giving many output values. It is these calculated values that make the spreadsheet so useful. In a financial sheet it maybe a single calculation from a very large number of entered items, typically the total money spent on items purchased over a period of time. On the other hand it may make a multitude of calculations from a small number of entered values. In this chapter, calculating all the X and Y co-ordinates from just two entered values, the number of holes and the diameter on which these are placed.

It is such a case as this that makes the use of spreadsheets so useful in the home workshop. The speed at which this takes place can be a surprise to a new user of a personal computer; add new values for the number of holes and the PCD and the required values will appear almost instantly.

Give it a try

The following is an example of a simple spreadsheet set up to calculate the volume of a cylinder where the user adds both its diameter and length.

	A	B	C	D
1	**DIAMETER**	**LENGTH**	**VOLUME**	
2				
3				

Initially cells A2 and B2 will be left blank with cell C2 having the formula for the volume of a cylinder added. However, the formula will not appear in cell C2 so the sheet will initially appear as above. The formula will then appear elsewhere on the screen, normally on the lower line, but only when the screen cursor is placed in that cell. The formula, Volume = $\pi x R^2 x L$ will though be set up in terms of cell references and will therefore be $\pi x(A2/2)^2 xB2$. Most, if not all, computer programs use * as the multiplication sign so the formula will read $\pi*(A2/2)^2*B2$. This is a very simple application but one that would be very well worth setting up if you are a new comer to spreadsheets. You will soon find the advantages of being able to enter new values for diameter and or length and for the volume to appear immediately.

If we now enter a diameter of 10 and a length of 2 the screen will read

	A	B	C	D
1	DIAMETER	LENGTH	VOLUME	
2	10	2	157.1	
3				

If the program cursor is placed on C2, then elsewhere on the screen the formula for that cell, $\pi * (A2/2)^2 * B2$, will be displayed, whilst still displaying 157.1 in the list.

The program will calculate, in the background, the answers to very many decimal places but you can format each column to display values with the number of decimal places as appropriate to the application. All columns can be individually configured in terms of width, number of decimal places, etc. In a financial sheet the column for the value of the item purchased will be set up for numerical data and probably be 8 characters wide, 5 for whole pounds, 1 for the decimal point and 2 for the pence. The column to carry the item description will be set up for text and have a much larger width, say 30 characters.

I should explain that in addition to providing cells for inputting values and others containing formula, heading cells are also included at the spreadsheet design stage. The Diameter, Length and Volume headings in the above are an example.

I have above presented the formula in single line format, rather than the easier to understand multi line format used earlier in the chapter, as this is the way formulae will have to be entered into the spreadsheet.

Multiple calculations

The spreadsheet really proves its worth where multiple calculations are involved and where there are many more columns and rows. The need to calculate X and Y co-ordinates at numerous angles is a good example. However, unless you are expert in setting out the formula it will be necessary to proceed systematically. Let us take the slightly more complex example of working out the touching holes on a PCD as illustrated in **SK3**.

First, the hole diameter must be calculated based on the outer radius and the number of holes chosen. In addition to headings, etc. set up at the design stage, four cells must be provided as follows:

1. For the number of holes chosen.
2. For the outer diameter.
3. The cell in which the program displays the calculated value for the angle between adjacent holes.
4. The cell in which the program displays the calculated value for the hole diameter.

Cell's A2 and B2 should be set up for numerical entry and C2 and D2 having the formulae for calculating the angle between

	A	B	C	D
1	HOLES	OD	ANGLE	DRILL SIZE
2				
3				

holes and the drill size. As already stated the formulae do not appear in the cells but elsewhere on the screen. I should add at this stage that as with all computer programs there will be subtle differences but the basic principles indicated in this chapter should apply.

Building up a formula for adding to a cell can be somewhat complex as the formula has to be entered as a single line and the correct usage of brackets observed to ensure that parts of the formula are calculated in the correct order. By far the best way is to build the formula in stages and observe that the correct value is arrived at each stage.

Starting first with the easy one C2. The formula for angle A is given in **SK3** and when placed in cell C2 would read = 360/N where N being the number of holes. However, the value for N will have been entered in cell A2 therefore the formula in C2 should read = 360/A2. Note that / is used for divide and * for multiply in spreadsheet programs.

The formula in D2 is though much more complex being that given for "d" in **SK3**. Build this up in stages starting at the innermost expression, that is A/2. Now remembering that A (the angle) is the value in cell C2, therefore enter the formula = C2/2 and observe that the result is half the angle in C2.

Enter the edit mode for the cell and change the formula to read = sin (C2/2) and check this against some trig tables or your scientific calculator. The brackets ( ) are essential else the program will give you half the value of sine C2 that is quite different from the sine value of half of C2 being what is required. The brackets say do C2/2 prior to choosing the sine value.

Again enter edit and change the formula to read = 1/(sin(C2/2)) and check that the value 1 divided by sin(C2/2) is the result, take note of the extra brackets. Continue going through the following sequence checking the value at each stage, next = (1/(sin(C2/2)))+1 and finally, = B2/((1/(sin(C2/2)))+1). This may seem a slow process but as the value appears immediately the formula has been edited, it is no more that a couple of minutes. Entering the formula at one go and leaving out a crucial bracket could take much longer to solve, of course if you are experienced you then enter it a one go.

One further point regarding the above, your spreadsheet may use radians rather than degrees so the above formula will need adjusting to suit. For the reader who is not familiar with radians, 360 degrees equals 2 x π radians. In this case sin(C2/2) would read

sin((2 * π * C2/360)/2)

Cells A2 and B2 have been set up for numerical entry and could be 3 characters for A2 (up to 999 holes) and 7 characters for B2 (up to 999.999 for the outside diameter). However, width of columns will often depend on the heading required at the top. For example column A may have to be 7 characters wide, that is five for the word "holes" and a space either side to separate it from its adjacent heading. Headings can take up more than one row.

If in the case of the word "holes" "number of holes" was preferred then the heading could span rows 1 and 2 with the value being allocated to row 3. The columns do not have to be wide enough to display the formulae, these are displayed separately and one at a time as the cell is selected. The two screen prints help to illustrate this, more later.

If carrying out the above was to be a one-off calculation then you would be better with a piece of paper and your calculator. If though you were expecting to make the calculation frequently then save the sheet to a file and call it up next time you need it, all that will be needed would be to enter new values for number of holes and/or outer diameter. In any case, as mentioned above, even for a single application you may have to carry out the calculation a number of times to arrive at a suitable hole size.

As already mentioned, the real benefit of using a spreadsheet becomes apparent where multiple calculations are required with the need for multiple X and Y co-ordinates being an excellent example. Five columns will be needed as follows:

Column A. Hole Number.

Column B. X co-ordinate relative to the circle centre.

Column C. Y co-ordinate relative to the circle centre.

Column D. X co-ordinate relative to extreme co-ordinates.

Column E. Y co-ordinate relative to extreme co-ordinates.

The formulae for these will be those included in the paragraph headed "**The Formula**" on page 38. They will need to be written on a single line with all the brackets in the required places, typically for the X co-ordinate relative to the circle centre = R cos((P-1) x 360/N). To make the formulae work though R, P and N will have to be substituted with the cell references for the cells containing the values.

Duplicate and Paste

If you set up your spreadsheet for up to 100 holes, or more, you may feel that typing in the formula 100 times and similarly for the other three columns, is a task beyond what is acceptable. Fortunately, the facilities "duplicate" and "paste" limit the work involved considerably. Having typed the formula in for a single line and checked that it worked it could then be duplicated into the remaining 99 cells. However, after having duplicated say 4 individually the block of 5 could be duplicated and pasted in five at a time reducing the work significantly.

This though is not the full story as whilst the values for R (radius) and N (number of holes) are constant, and will be picked from the cells at the top of the sheet (R is in C11 and N is in A6 in the screen print 2), the value for the hole position "P" (A16, A17, etc.) progresses by one on each row. All is not lost as when the formula is pasted for the first time, the program will seek out each variable and ask if it is absolute (the same value each time) or Relative (changes each time relative to another cell). Having indicated that R and N are absolute and P relative it will not ask when the formula is pasted in further cells so the task is still an easy and quick one and can be done in blocks rather than one line at a time. Do though set up only a few lines and test your program thoroughly before pasting in the full number of lines.

This still has the column "A" which contains the hole position number. If, for

```
         A              B              C              D          E
1              CALCULATES CO-ORDINATES OF HOLES ON A PCD
2   --------------------------------------------------------------------
3                 USER ENTERED ITEMS
4   NUMBER OF                         Radius at
5   HOLES                             hole centre
6                 5                          40.000
7   --------------------------------------------------------------------
8                   CALCULATED VALUES
9                                     Angle
10                                    Between holes
11                                           72.000
12  --------------------------------------------------------------------
13                           RELATIVE TO             RELATIVE TO
14                          CIRCLE CENTRE        EXTREME CO-ORDINATES
15  HOLE NUMBER          Co-ordinate X  Co-ordinate Y     X         Y
16                1             40.000              0  80.000    40.000
17                2             12.361         38.042  52.361     1.958
18                3            -32.361         23.511   7.639    16.489
19                4            -32.361        -23.511   7.639    63.511
20                5             12.361        -38.042  52.361    78.042
21                0                  0              0       0         0

B16/Formula: IF(A16,C6*COS((A16-1)*(((2*PI)/360)*C11)),0)
```

SCREEN PRINT 1

example, you are working to a maximum number of holes of 100 in which case you could just type in, when designing the spreadsheet, the numbers 1 to 100 down column A. This would work quite well but when requesting co-ordinates for say 10 holes on a PCD it would continue calculating through the 100 lines as though you were going round the circle 10 times. When on the screen the lines beyond 11 up could be ignored but if as is likely a printout is to be taken, extra sheets would be printed out. If therefore the sheet could be made to stop at hole 10 an all round tidier situation would result.

Rather than just typing 1 and upwards it could be arranged for the formula to do this. Taking screen print 2 as an example cell A16 would just have the figure 1 typed in. Cell A17 would though have the simple formula = A16+1. When pasting in further cells and requesting these to be relative we would get, = A17+1, = A18+1, etc.

Having now arrived at the hole number by this means it will open up the possibility of extending the formula so as to halt the progression at the number holes required. However, to do this will involve including some logic expressions in the formula and this will increase the complexity quite considerably and if new to spreadsheets it is best left at this stage. With this done the program will calculate the values for the number of holes required but then continue as if going round a second time and more.

To achieve a tidy result it would then be a good idea to copy the file to another and in this block delete all the records

	A	B	C	D	E
1	CALCULATES CO-ORDINATES OF HOLES IN AN ENCLOSEING OUTSIDE DIAMETER				
2	--				
3		USER ENTERED ITEMS			
4	NUMBER OF	OUTER			
5	HOLES	RADIUS			
6	5	0.650			
7	--				
8	PROGRAM CALCULATED ITEMS				
9		Hole diameter	Radius at	Angle	
10			hole centre	Between Holes	
11		0.481	0.409	72.000	
12	--				
13		RELATIVE TO		RELATIVE TO	
14		CIRCLE CENTRE		EXTREME CO-ORDINATES	
15	HOLE NUMBER	Co-ordinate X	Co-ordinate Y	X	Y
16	1	0.409	0	0.819	0.409
17	2	0.127	0.389	0.536	0.020
18	3	-0.331	0.241	0.078	0.169
19	4	-0.331	-0.241	0.078	0.650
20	5	0.127	-0.389	0.536	0.799
21	0	0	0	0	0

B16/Formula: IF(A16,C11*COS((A16-1)*(((2*PI)/360)*D11)),0)

SCREEN PRINT 2

above the values required. This could then be printed out for use in the workshop. The sheet would still contain the formulae up to that value and could be used again with that number of holes for subsequent applications.

Logic

With this we are now arriving at a much more complex use of spreadsheets and one that most will never see a need to use. I would therefore suggest that unless you are conversant with logic expressions you leave your sheet at this stage. Eventually, when becoming fully conversant with spreadsheets this far, you could then take time to look into the logic provisions of your program. However, rather than leaving the subject without any further explanation the following should give an insight into the subject.

Consider column A, carrying the number of each hole, this could be set up with some simple logic that halts the calculations once the hole number has reached the number of holes required. Trying to express this verbally the logic would state, "IF the value in the previous cell equals the number of holes required enter "0" IF NOT enter a value one higher than in the previous cell.

Whilst this would work for the first line after completing the number of holes required it would not work for the next line as the previous value would not equal the number of holes required but would equal nought. It would as a result add one to this starting the sequence again, because of

this a multiple IF has therefore to be used. This would state "IF the value in the above cell equals "0" then enter "0", IF NOT, IF the value in the previous cell in the column equals the number of holes required enter "0" IF NOT enter a value one higher than in that cell".

To ensure that the X and Y values also display a value of zero the formula should include an IF clause as illustrated at the bottom of the screen prints if this were not done the co-ordinates would be worked out on basis of zero in column "A" giving irrelevant values. From these brief comments on the use of logic it can be seen that the complexity has been raised significantly. Please do not however let this put you off attempting to use spreadsheets in their simpler form.

Screen Prints

I will finish with a few brief comments on the screen prints published. **Screen 1** is for calculating holes on a PCD whilst **Screen 2** calculates values for holes in an enclosing circle.

The only major differences are that in 2 the hole diameter (B11) has been calculated by the program as has the radius on which the holes are to be placed (C11).

It is not visible on the print but the cursor was at cell B16 when the screen print was taken and the formula for that cell is displayed at the bottom left of the screen. Moving the cursor to other cells would cause their formula to be shown. Note the IF command that basically states IF A16 is zero display zero in B16 IF NOT then calculate as per formula.

One other important point worth repeating is that your spreadsheet may use radians to describe angles rather than degrees. Therefore, as there are 2 Pi radians in a circle then say for 70 degrees the number of radians is 70*2pð/360. This should be evident in the formula for B16.

The screen prints also illustrate another important feature of spreadsheet design. Considering screen print 2 it can be seen that lines 3 to 6 are used for date inputed by the user with the remainder displaying values calculated by the spreadsheet. These though can be divided into two categories, lines 8 to 11 displaying values calculated the once only whilst lines 13 upwards repeat basically the same calculation but for each hole position.

Of greater significance is that when a column has been allocated a width and formatted (number of decimal places, etc.) this will apply to all items down the column. Typically, had "Outer radius" been placed in A6 and "No. of Holes" in C6, hole numbers would have to display as 1.000, 2.000, 3.000, etc. and number of holes as 5.000 - this can complicate the design of some sheets. Having made the point it maybe that some more modern and adaptable spreadsheet programs do allow characteristics of a column to change down their length.

In their simplest form spreadsheets are not that complex and yet still very useful and time saving. They also avoid any possibility of errors due to tapping incorrect values into your calculator, easily done when many hundreds of calculations are to be carried out. So what are you waiting for, go on, give spreadsheets a try.

Chapter 6

Simple Shop-made Dividing Devices

The next four chapters deal with items that can be made in the home workshop. The reasons for this approach will be numerous but are likely to be mainly.

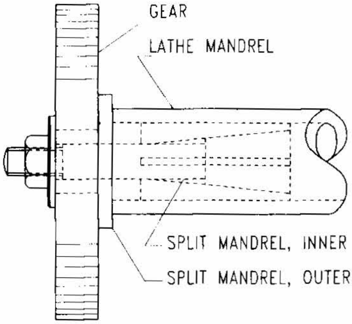
1.The workshop owner gets much satisfaction in making workshop tools.
2. Because of limited use cannot justify the expense of a commercially made item.
3. Item not available commercially.

Some of the items in this chapter, along with the Lining tool in Chapter 9 are examples of items not available commercially. It is assumed that any reader embarking on projects involving dividing will have arrived at a reasonable understanding of basic workshop practices. Because of this, details of manufacturing techniques will be reserved largely to areas of greater complexity.

Lathe mandrel gear mounting

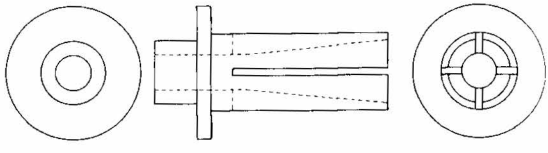
The method of mounting a gear on the rear

1. The two parts that make up the lathe mandrel gear mounting assembly.



NO DIMENSIONS ARE GIVEN AS THESE WILL DEPEND ON THE LATHE TO WHICH THE MANDREL IS TO BE FITTED.

LATHE MANDREL GEAR ASSEMBLY

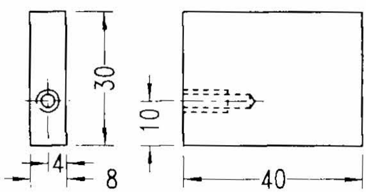


MATERIAL STEEL 230M07

SPLIT MANDREL, OUTER.

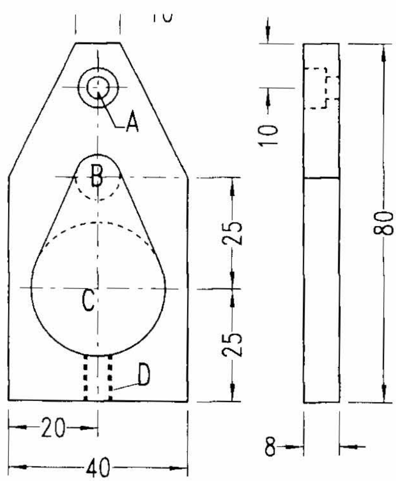
MATERIAL STEEL 230M07

SPLIT MANDREL, INNER



HOLES M5 X 10 MM DEEP, 1 OFF
MATERIAL 40 X 8 STEEL 070M20

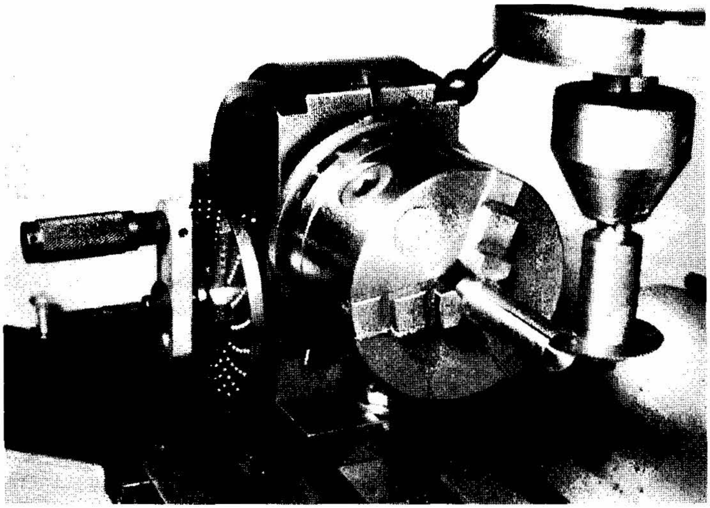
DRIVING PLATE.



HOLES
A 5.5 MM CB 9 MM X 5.5 DEEP
B 10 MM
C 30 MM
D M6
MATERIAL 40 X 8 STEEL 070M20

COMPONENT PLATE.

2. *Slitting the outer part. This uses the direct indexing disk seen behind the chuck to set the positions.*

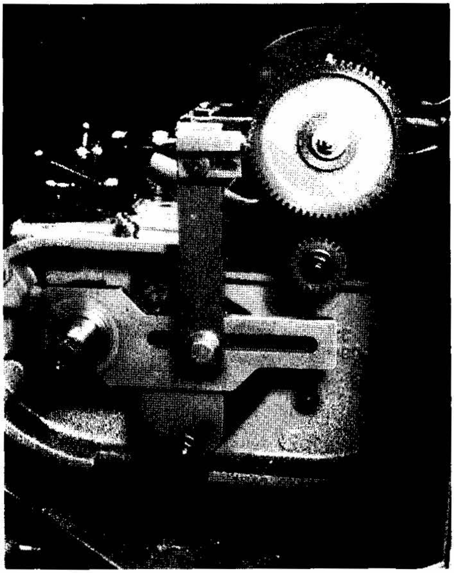


end of the lathe spindle for dividing purposes is shown in the published assembly and parts drawings. No dimensions are given as they will vary from lathe to lathe.

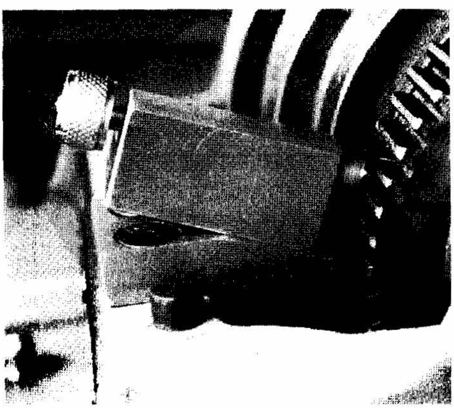
Manufacturing this is straightforward, place the material in the chuck for the outer part and with sufficient projecting to machine the whole part at this stage. Use left and right hand knife tools to machine the two parallel portions without removing the part from the chuck ensuring as a result that they are concentric. Set the angle of the top slide and make the internal taper, leaving the top slide at this angle for the other part. Next machine the parallel portion of the inner part making the thread also. Turn the part in the chuck holding on the portion just turned and machine the taper **Photo 1** shows the two parts on completion.

I am not including any details for the design of the detent mounting as the method of mounting this will vary widely. However, using the changewheel quadrant would seem a good starting point for consideration. The plunger in the detent assembly should be made a close sliding fit in its housing so as to minimise backlash when in use. Despite this, backlash should always be taken up manually and in the same direction, even with a precision dividing head. Again I have not included any details for the detent assembly but those in Chapter 8 (parts 41 and 42) should prove a basis for any design.

Slitting the outer component is illustrated in **Photo 2** and as can be seen it is a simple operation for the dividing head. However, it serves to illustrate a feature of this form of head which has not been mentioned so far. Just visible behind the chuck is a plate containing a ring of 24 holes. This permits direct indexing of any division possible with a 24 hole plate, that is 2, 3, 4, 6, 8 and 12. The head is still rotated via the worm/worm wheel from the manual handle but is locked in place using a peg in the top hole position. The peg is



3 Above. A typical detent mounting, it will of course vary depending on the lathe to which it is being fitted. Because of limited space this photograph has been taken via a mirror.
4. Below. Bull wheel dividing attachment.



advanced using the small lever partly visible top right of the dividing head.

Photo 3 shows a typical assembly, but do not be confused, due to lack of space the photograph has been taken via a mirror.

Bull wheel detent

This is another case where the design will depend very much on the lathe to which it is being applied. However, once again the detent assembly in Chapter 8 should prove a basis. **Photo 4** shows the method applied to a *Myford* Series Seven lathe.

Chuck back plate dividing

Whilst not applicable to today's workshops to the same extent as in the past, dividing using drilled holes around the chuck's backplate can still have its place. Drilling the holes may though seem a daunting task but as the system is really only appropriate for lower numbers there is no reason why this should be. Using the method of a divided paper strip, as described in Chapter 3, will make the process an easy one. **Photo 5** shows a chuck prepared for twelve divisions. The back plate is to be centre punched on the markings and then drilled with the required holes, 3 mm diameter and 3 mm deep would be about right. Care in positioning the marked strip will be necessary to ensure that the holes do not conflict with the back plate's fixing as they may be close to the edge.

Having also divisions of 5 and 10 may be desirable in which case a ring of 60 holes would appear to be required. This need not be the case as two rings of holes, one of 10 and one of 12 could be made. In this case, positions 1 and 7, from the 12 hole ring, sharing the same places as holes 1 and 6 from the 10 hole ring. It may though

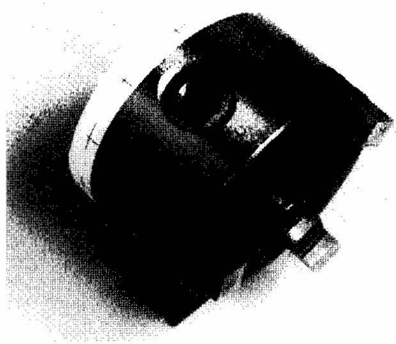
make it difficult to avoid the back plate's fixings.

Dividing plates

Having a semi-universal dividing head and a good range of dividing plates there will still be many divisions that are not possible, even at lower numbers. Typically a need of 53 divisions can only be achieved using a dividing plate having 53 divisions itself. As this is a number greater than is normally available on the smaller plate sizes supplied, another plate would have to be purchased. If also it is for a one off application such an expense may be difficult to justify. Making ones own may therefore be the way forward.

An interesting feature of using a dividing plate via a worm/worm wheel with the same number of holes on the plate (53 in this example) as there are divisions required, is that the number of holes traversed will always be equal to the worm ratio. Assuming a ratio of 40:1 the number of hole traversed for one turn at the output will be 40 x 53 and the number of holes traversed for one division will be 40 x 53/53 = 40. This would be achieved with one turn plus 13 holes.

Having mentioned 53 as a division and stating that it can only be achieved with a 53 hole plate, I should point out that this is because it is a prime number. Unless a Universal dividing head is available, rather than a Semi universal head, prime numbers always require a plate having the same number of holes, excepting for lower numbers where a multiple may be practical, typically for 19 divisions a 38 hole plate.



5. A chuck back plate being prepared for drilling holes for dividing purposes on the lathe.

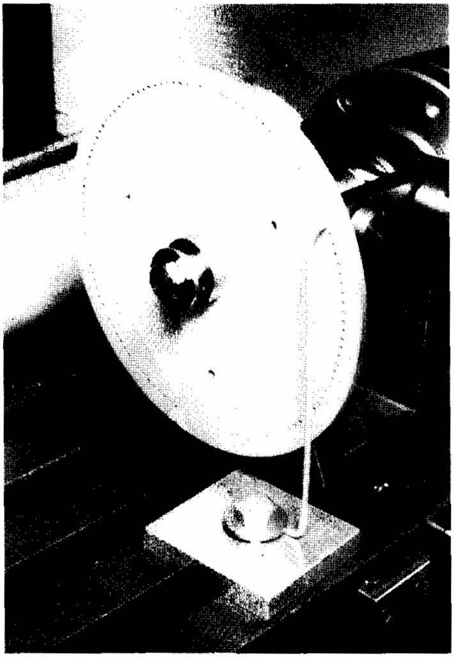
For more information regarding prime numbers see Chapter 10.

Using X and Y co-ordinates

By far the most accurate method to produce a division plate would be to work out the X & Y co-ordinates and use the milling machine to position the holes. For the lower numbers this would certainly be the way to proceed but for higher numbers the method could be a little tedious and great care would be needed in setting the table's position for each division. As a precaution, lightly mark out the positions with a centre drill and inspect the result before removing the plate from the table. Any obviously out of position hole can be set up again using the available co-ordinates, marking again, this time with a larger centre drill. Do also mark the plates centre position whilst on the table as concentricity of the mounting position is important.

Using a Rotary table

Using a rotary table would also be worth considering and where possible be as accurate as using co-ordinates. The limiting



6. *A 125 dividing plate made using an actual size CAD print.*

factor would be if the angle between divisions could easily be established using the table's calibration. Typically, a need for 45 divisions would require an angle of 360/45 per division, being 8 degrees. With a 60:1 ratio worm/worm wheel this would require, one turn (6 degrees) plus 2 whole degrees using the table's calibration making it a practical proposition.

If the need is for 46 divisions, at first sight a relatively simple requirement, the angle between divisions would be 360/46, being 7.826087 degrees. This would be one turn plus 1.826087 degrees on the table's calibration for each division, obviously an impractical proposition. Using the rotary table has therefore limited use for making dividing plates.

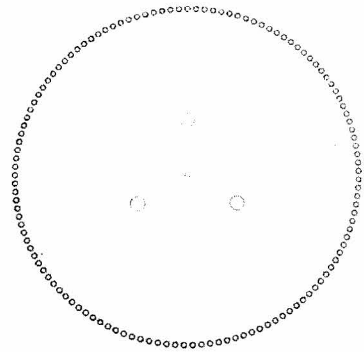
However, as a last resort, a list of values from the start could be produced 7.826087, 15.652174, 23.478261 and 31.304348, etc. These could then be converted to 1 turn + 1.826087, 2 turns + 3.652174, 3 turns + 5.478261 and 5 turns + 1.304348, etc. Finally they could be simplified 1 turn + 1.83, 2 turns + 3.65, 3 turns + 5.48 and 5 turns + 1.30, etc. then used to set up each position as accurately as is possible. This would avoid an accumulating error and probably be acceptable where a high degree of accuracy is not being aimed at. If the plate were used via a worm/worm wheel, the improvement in accuracy this provides would be a distinct advantage.

A Computer Method

If you, or a friend, have access to a computer equipped with a CAD program there is another method that may prove useful. Placing any number of holes on a PCD using a CAD program is both easy and fast. Place a small circle for the dividing plate centre plus just one on the PCD then asking the program to repeat this round the circle the number of times required and the result will appear almost immediately.

Print this out and fix it to the plate already prepared. Centre punch through each small circle, also that in the centre, remove the print and examine result looking for any punch marks which are obviously misplaced. Make any adjustments necessary and use a centre drill to mark each position, again inspect. The ring of holes can then be drilled. Being very quick compared to working to X/Y co-ordinates it is an ideal method for large numbers of

7. Photo of the dividing plate print out.



CAD PRINT OUT FOR 125 DIVISION DIVIDING PLATE

divisions. **Photo 6** shows a plate having 125 divisions being used which was made this way. **Photo 7** shows the computer printout. Making the circles on the printout small, say 1 mm diameter, will help to ensure that the centre punch marks are made accurately.

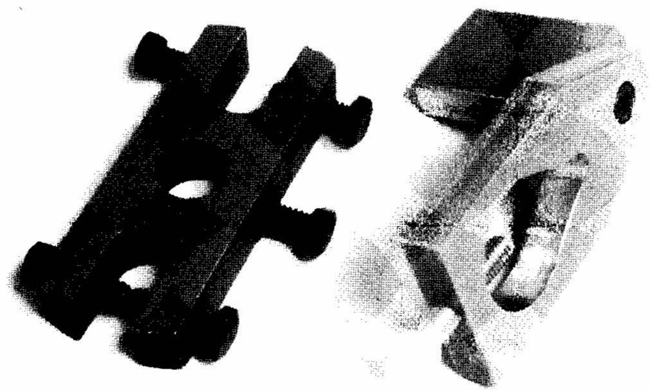
Whilst fast, the system does have limitations, mainly accuracy. The computer data is of course extremely accurate but may not be maintained at the printout stage. Having tried the method with a number of printers very small errors in the printers' feed mechanisms result in the PCD sometimes being very slightly oval. Not surprisingly, a print out using a professional pen plotter produced a perfect result, at least as far as available measuring methods would show. A cheap dot matrix printer also did remarkably well, with ink jets and laser printers showing varying amounts of error, even here no more than 1 mm on the PCD.

At worst, the errors in the diameter would produce only minute errors in angular spacing and so would be perfectly adequate providing the radius error of the PCD could be accommodated in the mechanics. If using a conventional detent its plunger would not engage reliably due to the varying radius. **Photo 6** shows how this was overcome using a heavy gauge, spring wire detent that would cope with sideways errors whilst still holding the plate in terms of rotation. If the plate was to be used frequently on a normal dividing head with plunger type detent, the plate could be used to make a second plate - the holes on this would then be on a constant radius. An interesting feature was that the wire having a slight taper on its end the result was totally backlash free, almost impossible with a conventional detent.

Incidentally the plate was used to slit a small disk 125 times to make an electronic pulse unit for use with a digital readout for an eight TPI leadscrew.

Made on the lathe's faceplate

For a simple plate, using the mandrel mounted gear as described at the start of this chapter would be an obvious choice. For more complex numbers, mount a disc onto the face plate and using a suitably divided paper strip round the outer edge of the faceplate will enable the disc to be marked for making a dividing plate. The positions can be established using an automatic centre punch mounted on the top slide, or a small drilling spindle. This process should make a dividing plate accurate enough for most applications,



8. Driving dog for between centres work, together with driver (on the left) supplied with the dividing head.

especially if used via a worm/wormwheel, rather than direct. See **Photo 4** Chapter 3.

Taking the need for 53 divisions, as mentioned earlier in the chapter. If using a 150 mm diameter faceplate and marked with 53 divisions on its periphery it will result in divisions of 8.89 mm wide, so a fair degree of accuracy should be achievable.

A Between Centres driving dog

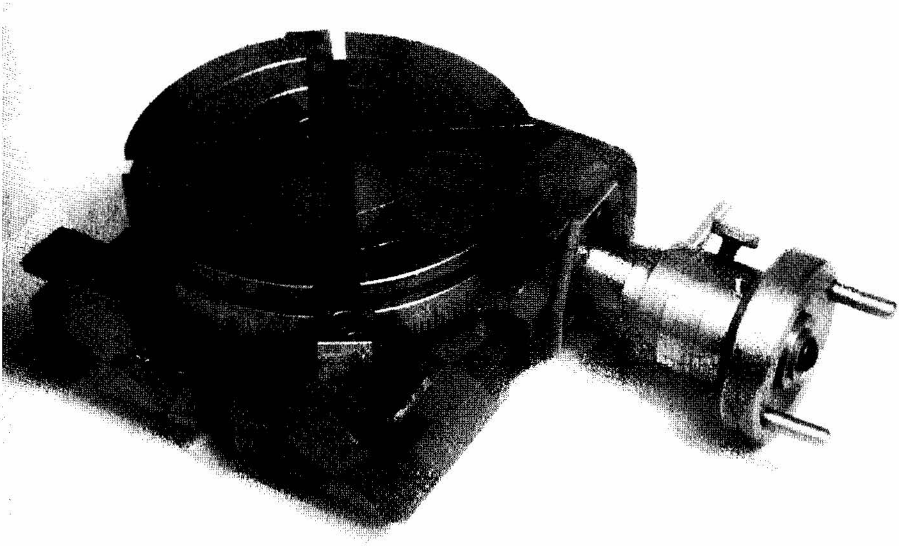
Not having been able to locate a commercial driving dog suitable for use when dividing between centres, I am including details of the item I have made myself. As described in Chapter 3 (see **Photos 12** and **13**) the dog needs to be firmly held by the driving device on the head itself. To cope with differing workpiece diameters a flat plate is used for the driven portion of the dog, it is also drilled and tapped off centre so that it can be rotated to extend the range even further, see assembly drawing. **Photo 8** shows the driver, supplied with the dividing head, on the left, and the driving dog on the right. The published drawing should give all the details necessary for manufacture.

Rotary tables

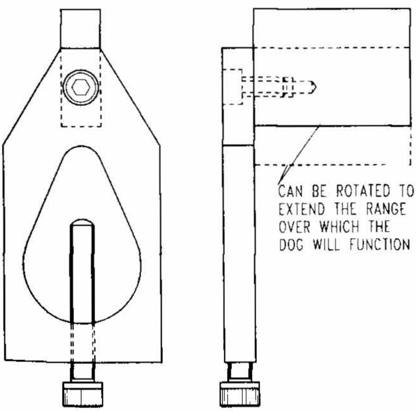
Making rotary tables in the home workshop is not really in keeping with the title of this chapter, "simple dividing devices", but is included as it is the most appropriate place in view of only a paragraph being required.

A number of suppliers to the home workshop provide designs and kits of materials for making workshop equipment, rotary tables being one such item. **Photo 9** shows a typical 100 mm table that has been made this way, larger sizes are also available. If you like making workshop accessories then a rotary table would make an interesting project. None, to my knowledge include facilities for mounting division plates but designing this in should not be unduly difficult.

The design for a basic dividing head is the subject of the next chapter. Whilst basic, it will be sufficiently adaptable to meet the needs of many workshop owners.



9. A 100 mm home made rotary table. Castings for these are available from a number of suppliers and in other sizes.

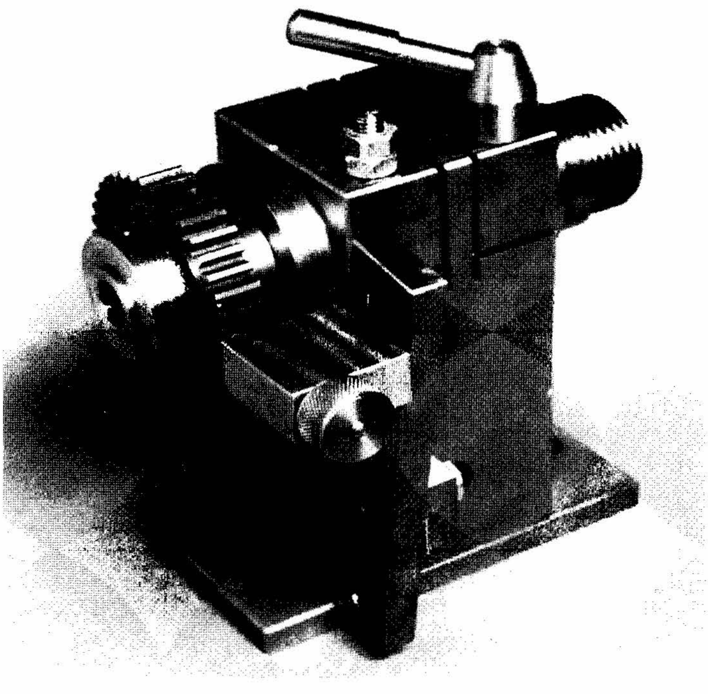


BETWEEN CENTRES DRIVING DOG

Chapter 7

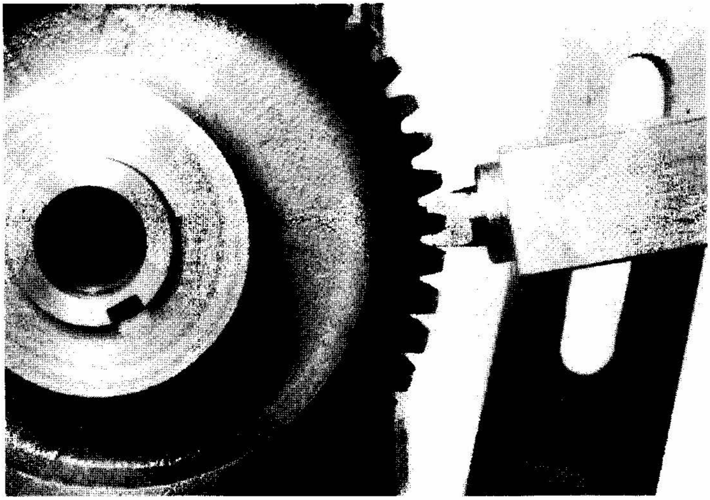
Shop-made Basic Dividing Head

For many workshop owners the dividing head featured in this chapter will be more than adequate for their dividing requirements. It does though rely on a set of lathe changewheels being available as it uses these to provide the divisions. Using a single gear, **Photo 1**, will provide many of the more usual divisions namely 2,3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, and 75 using the most common set of gears, 20 to 75 by 5's. With a forked detent, **Photo 2**,



1. The single gear version of the dividing head. (indexer)

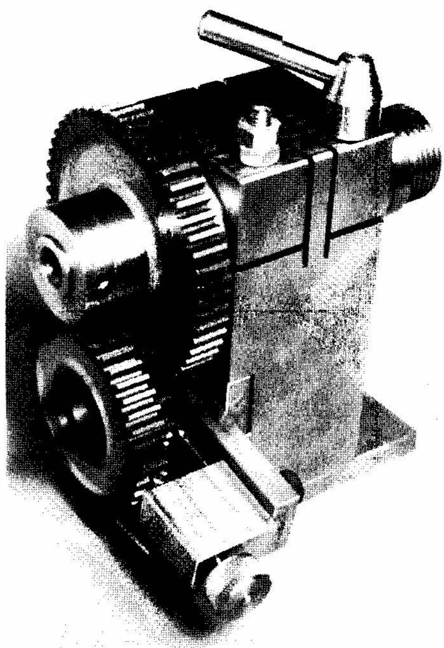
2. *Close up of the forked detent.*



16, 18, 22, 24, 26, 28, 80, 90, 100, 110, 120, 130, 140 and 150 are also possible.

The range is further extended by the addition of a pair of gears as illustrated in **Photo 3**. This, essentially the same as adding a worm and wormwheel between dividing plate and the dividing head spindle. There is though one fundamental difference, a worm/ worm wheel configuration will always have a ratio to one, typically 40 : 1, 60 : 1, etc. A pair of spur gears may though have a more complex ratio, for example, gears of 45 and 20 will have a ratio of 9 : 4.

Considering the range of gears above, but only one of each, around 600 different combinations will be possible. This based on, any one of the gears being used as the dividing wheel, and as the driven. Also, replicating the situation when using a worm/ wormwheel, that is input runs faster than the output, the driver wheel must always



3. *The three-gear version.*

be smaller than the driven.

Whilst the arrangement will give divisions of up to 1050, double this if a forked detent is used there is considerable duplication and very many gaps, large at the higher numbers. On the basis that higher numbers are unlikely to be required, the table for this setup in Chapter 11 gives all possible values up to 100 that are not obtainable with a single gear. The table, having been produced with a computer program I have developed, covers all divisions mathematically possible. In some cases the head may need adapting to make some combinations possible. Typically, with the base plate fitted as seen in **Photos 1** and **3** there is a limit to the size of dividing gear that can be fitted. The base is mounted using 4 screws on a square formation that permits it to be rotated 90 degrees removing the restriction. In this position however it may not be easy to mount on a *Myford* Series Seven type bed. In any case some readers may wish to use the table in connection with a dividing head of their own design.

An interesting and useful feature of these numbers is that they, with only two exceptions, are achieved stepping from gear tooth to gear tooth. There is therefore no need to move across more than one tooth avoiding the complication that this brings.

Three possible higher numbers that may find a use are also included; these are 125, 200 and 360. In the case of 200 the workpiece rotates twice and for 360, seven times, see Chapter 4 for an explanation.

From a dividing aspect there really is no difficulty created by the workpiece rotating more than once and if a gear is being made it should not present a difficulty. If though a dial is being made, probably with three line lengths, ten's, five's and units, great care in the preplanning and the actual calibration will be required to ensure the line lengths are made in the correct positions. Probably the easiest way will be to make all lines initially of equal length, then marking the position of the five's and ten's with different coloured pencils. The workpiece can then be rotated, again using the dividing head, and the appropriate lines lengthened.

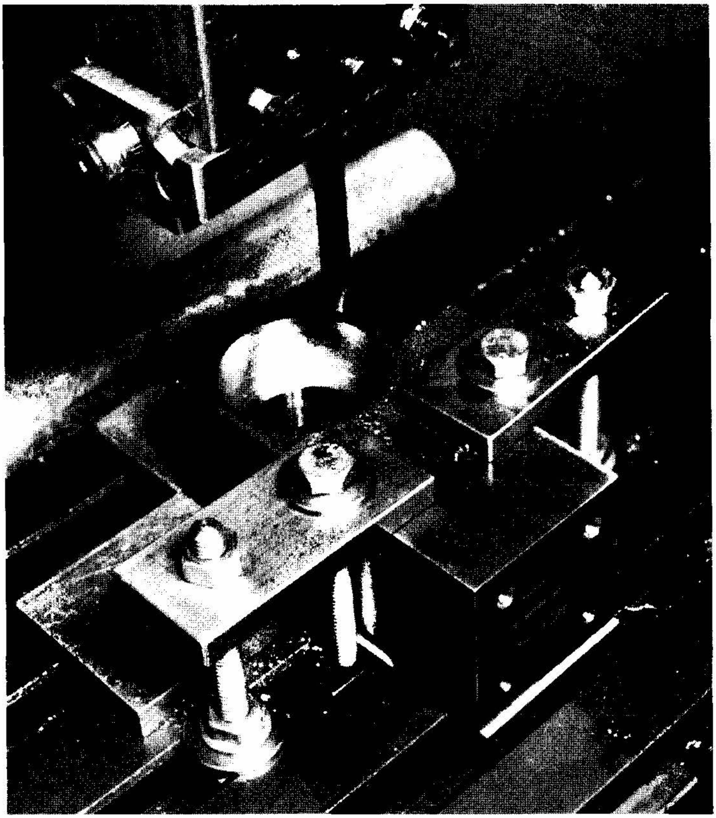
Manufacture

It is not my intention to go deeply into the manufacturing process as to do this for the shop made items would expand the size of the book beyond what is acceptable. It is also probable that the home workshop user who has arrived at the need to use a dividing head will have fairly well mastered the processes necessary to make this item. Should you though feel a need for greater help than this chapter provides, you may consider obtaining the following additional books in the Workshop Practice Series. Number 34, "Lathework - A Complete Course" and number 35 "Milling - A Complete Course". Construction of the dividing head in this chapter is covered in detail in number 35.

The Body Part 1

Photo 4 shows the 44mm diameter bores for the sleeve bearing being made. Just visible in the photograph are three support pieces mounted on the machine table. Providing the initial bore is central in the width (50mm) of the material, the support pieces will enable the part to be turned over and bored without the need for further measurement. A high degree of accuracy

4. Boring the body to take the sleeve bearing.



is not required as the bearings are eventually bored in situ.

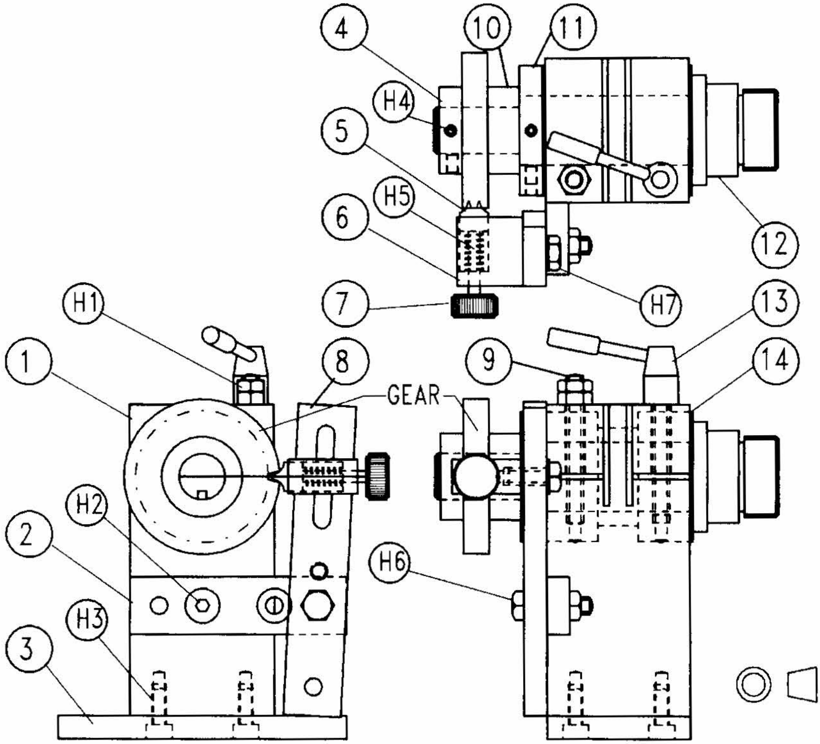
Fit the bearings using a two-part resin adhesive having made the bearing outer diameter about 0.05mm less than the bore into which it fits to allow space for a film of adhesive. Set up and bore to final diameter as shown in **Photo 5**, boring through both bearings at one pass to ensure alignment. Pay particular attention to clearance between boring head, workpiece and clamps, etc.

Slitting the body is straight forward, **Photos 6** and **7** showing the setups. However, depending on the diameter of the saw the setup in **Photo 7** may not fully complete the slit. In this case it will be necessary to complete it with a pad saw, or a piece of hack saw blade, part wrapped in cloth to provide a safe handle.

Spindle Part 12

First, make a plug gauge to accurately establish the diameter of the bore in the bearing. This will give you the dimension for turning the spindle bearing surface that

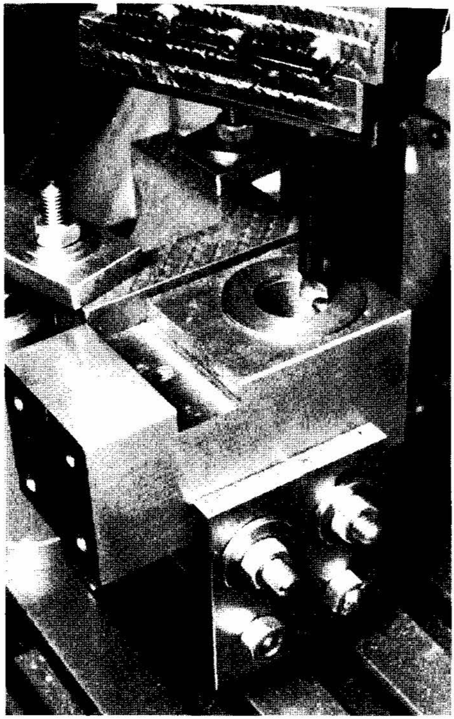
HARDWARE
H1 M6 NUTS 2 OFF
H2 M6 X 20 SOCKET CSK SCREW 1 OFF
H3 M5 X 12 SOCKET CAP SCREW 4 OFF
H4 M4 X 6 SOCKET GRUB SCREW 4 OFF
H5 SPRING TO SUIT
H6 M6 X 25 HEX HEAD SCREW AND NUT 1 OFF
H7 M6 X 16 HEX HEAD SCREW AND WASHER 1 OFF



NOTE. THE DETAIL PART DIMENSIONS SUIT GEARS WHICH ARE 5/8" WIDE, SPACER WASHERS MAY BE REQUIRED WHERE NARROWER GEARS ARE BEING USED.

DIVIDING HEAD - SINGLE GEAR DIVIDING

5. *Final boring the bearings.*

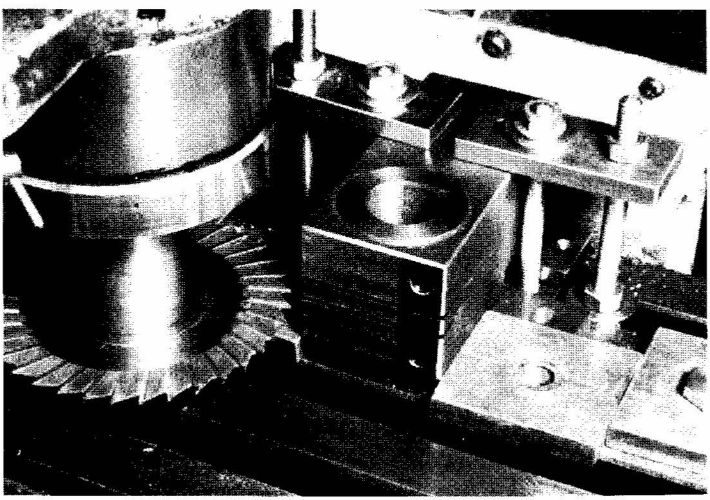


will need to be made using a left hand knife tool, making it impossible to use the spindle itself to test its fit.

The essential requirement for the spindle is concentricity of the four main surfaces - the gear mounting, bearing, chuck mounting and the internal Morse taper. This can only be easily achieved if these are made without removing the part from the chuck. To do this, machine the gear mounting, bearing surface and chuck mounting whilst supported by the tailstock centre. Then, remove the centre, position fixed steady, re-engage centre, set steady arms, remove centre, bore and make the taper.

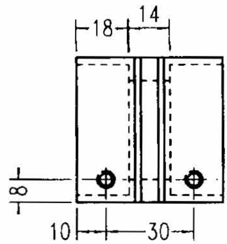
Remaining parts

The remaining parts should not present a problem for the majority of workshop owners but should you be at the learner stage then the books mentioned will be of



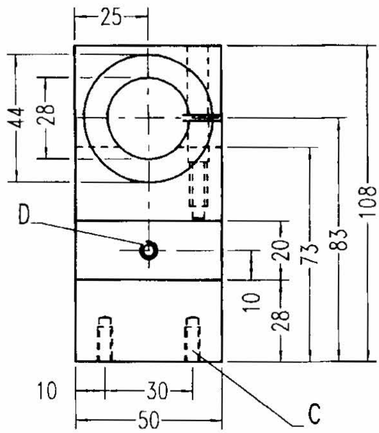
6. *Slitting to create the two separate bearings.*

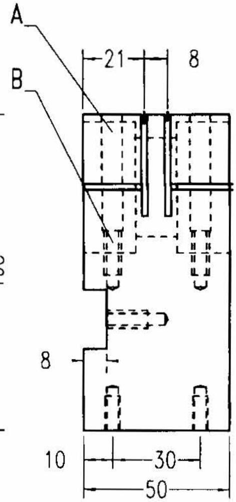
HOLES
A 6.5mm 2 OFF
B M6 X 15 DEEP 2 OFF
C M5 X 12 DEEP 4 OFF
D M6 X 14 DEEP 1 OFF
SLOTS 1.5 WIDE



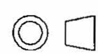
MATERIAL
50 X 50 STEEL 230M07

QUANTITY 1 OFF

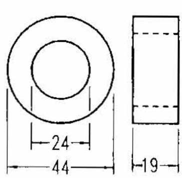




IMPORTANT NOTE
FIT BEARINGS (14), USING ADHESIVE, PRIOR TO DRILLING HOLES A AND B AND MAKING SLOTS.
FIT BEARINGS, DRILL AND TAP HOLES, FINALLY MAKE SLOTS



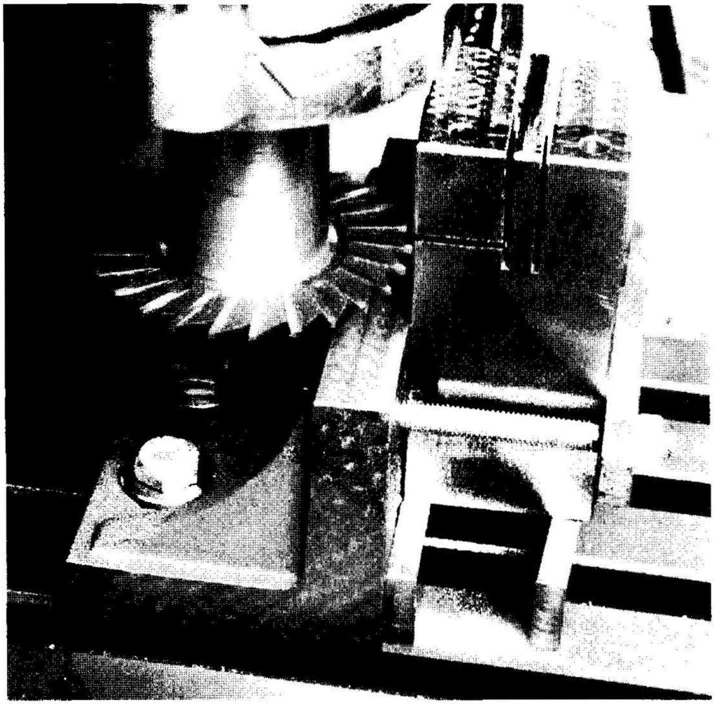
BODY 1.



MATERIAL
50mm DIAMETER CAST IRON
BORE TO 24MM AFTER FITTING TO BODY.
INITIALLY BORE 20MM DIAMETER

QUANTITY 2 OFF

BEARING 14.



7. Slitting to provide bearing adjustment.

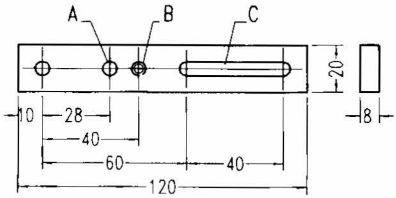
help.

The drawings do not indicate a method for coupling the two linked gears used on the three gear version as it is assumed that the parts used on the lathe for a similar requirement will be used, or an identical set made for the purpose. Also in this respect, the drawings assume gears having a 5/8in bore and 3/8in width, some dimensions may need changing if the gears to be used differ from this.

Assembly

On assembly the detent may need a little adjustment. To determine this, fully engage the detent then carefully remove it and turn through 180 degrees and re-engage. There should be no perceptible rotation of the dividing head spindle. If there is, then file a very little from the appropriate detent locating face and test again, repeat as necessary. Carry out a similar sequence, this time with the inner faces of the fork. Other than that, assembly is straightforward.

In the next chapter a much more advanced dividing head is detailed, yet again being made from stock materials is well within the ability of the majority of home workshop owners. Being a much more advanced design, making it should provide a real degree of satisfaction.

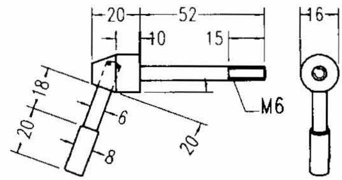


HOLE SIZES
A 6.2mm 2 OFF
B THREAD TO SUIT GEAR COUPLING USED
C 6mm WIDE SLOT

MATERIAL 20 X 8 STEEL 070M20

QUANTITY 1 OFF

DETENT ARM 8.

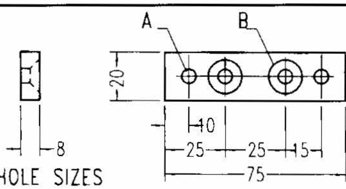


MATERIAL
16mm DIAMETER STEEL 230M07
8mm DIAMETER STEEL 230M07

DRILL AND FIT ARM ON ASSEMBLY

QUANTITY 1 OFF

LOCKING HANDLE 13.

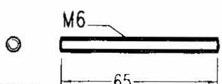


HOLE SIZES
A 6.2mm 2 OFF
B 6.2mm CSK 14mm DIAMETER 2 OFF

MATERIAL 20 X 8 STEEL 070M20

QUANTITY 1 OFF

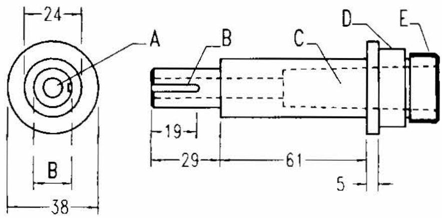
DETENT ARM SUPPORT 2.



MATERIAL
6mm DIAMETER STEEL 230M07

QUANTITY 1 OFF

STUD 9.



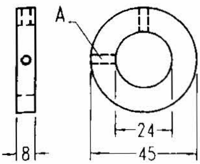
HOLE SIZES
A 8mm
B DIAMETER AND SLOT TO SUIT GEARS USED

C, D AND E AS PER LATHE SPINDLE NOSE

MATERIAL 38mm STEEL 230M07

QUANTITY 1 OFF

SPINDLE 12.

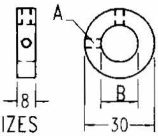


HOLE SIZES A M4 2 OFF

MATERIAL 45mm DIAMETER
STEEL 230M07

QUANTITY 1 OFF

THRUST BUSH 11.

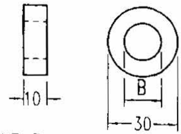


HOLE SIZES
A M4 2 OFF
B TO SUIT DIAMETER B PART 12

MATERIAL 30mm DIAMETER
STEEL 230M07

QUANTITY 1 OFF

GEAR RETAINING RING 4

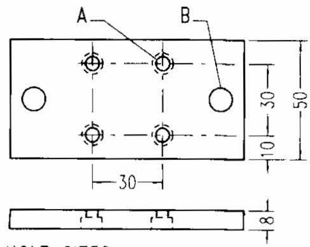


HOLE B
TO SUIT DIAMETER B PART 12

MATERIAL 30mm DIAMETER
STEEL 230M07

QUANTITY 1 OFF

GEAR SPACER RING 10.



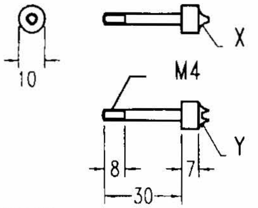
HOLE SIZES
A 5.2mm 4 OFF
C/BORE 9mm 5.5mm DEEP

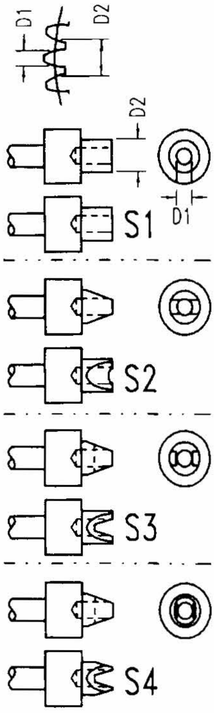
B SIZE AND POSITION, AND PART LENGTH, TO SUIT MOUNTING REQUIREMENTS

MATERIAL 50mm X 8mm
STEEL 070M20

QUANTITY 1 OFF

BASE 3.





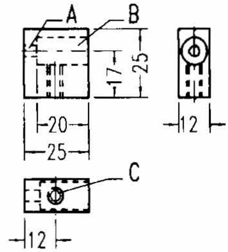
MATERIAL
12mm DIAMETER
STEEL 230M07

SHAPE TO FIT BETWEEN
TWO TEETH(X) AND
ACROSS A SINGLE TOOTH(Y)
SEE TEXT AND S1-4
FOR MORE DETAILS
DIAMETERS D1 AND
D2 ARE NOT CRITICAL

10mm DIAMETER TO BE A
CLOSE SLIDING FIT
IN PART 6

QUANTITY 1 OFF

DETENT 5.



HOLE SIZES
A 4.2mm 1 OFF

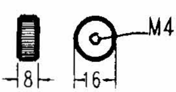
B 10mm 1 OFF

C M6 1 OFF

MATERIAL 25mm X 25mm
STEEL 230M07

QUANTITY 1 OFF

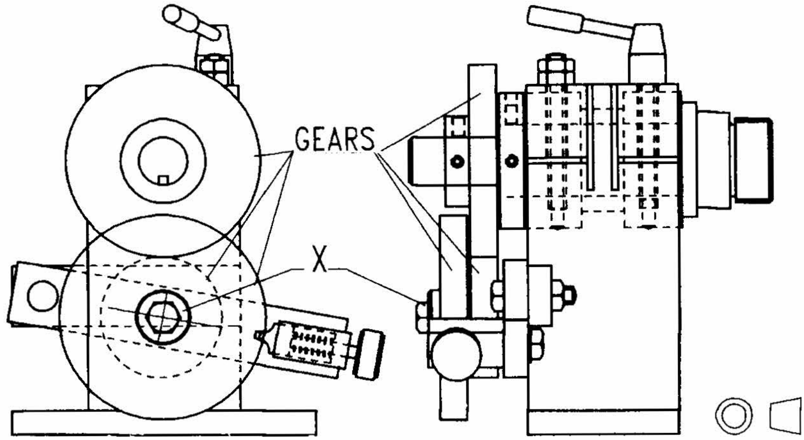
DETENT CARRIER 6.



MATERIAL 16mm DIAMETER
STEEL 230M07

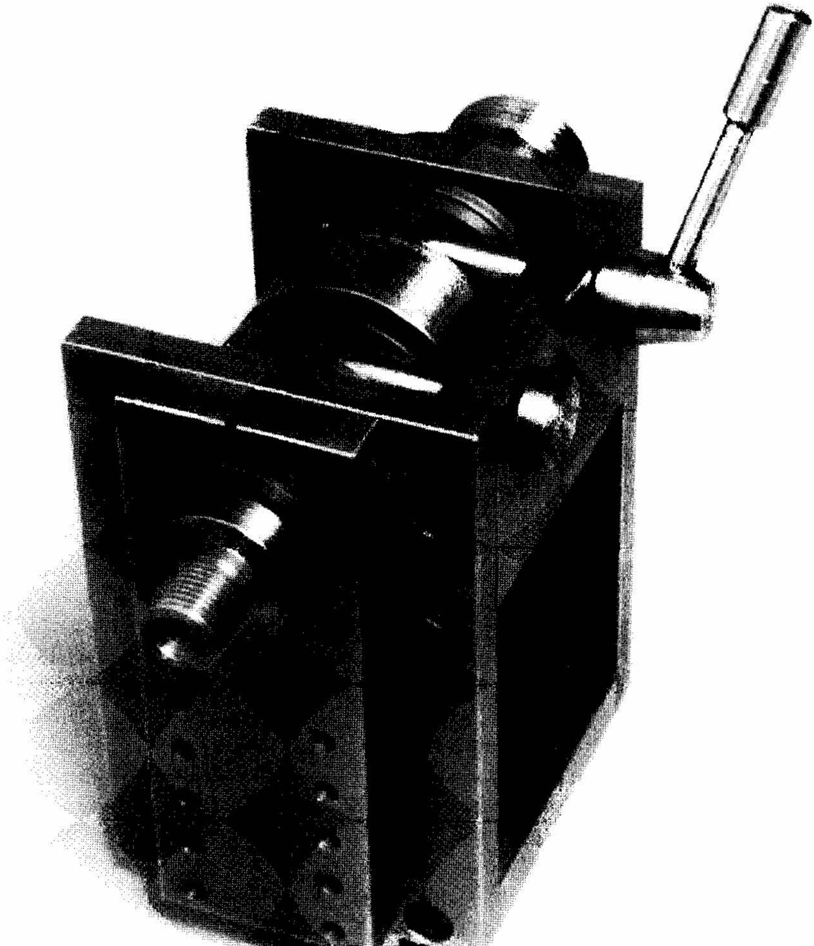
QUANTITY 1 OFF

DETENT KNOB 7.



NOTE. NO DETAILS ARE GIVEN FOR THE METHOD OF COUPLING THE TWO GEARS TOGETHER (X) AS IT IS EXPECTED THAT THE METHOD, AND PROBABLY THE PARTS, USED WITH THE AVAILABLE LATHE CHANGE WHEELS WILL BE USED.

DIVIDING HEAD - MULTIPLE GEAR DIVIDING



1. The dividing head's basic assembly.

Chapter 8

An Advanced Design Dividing Head

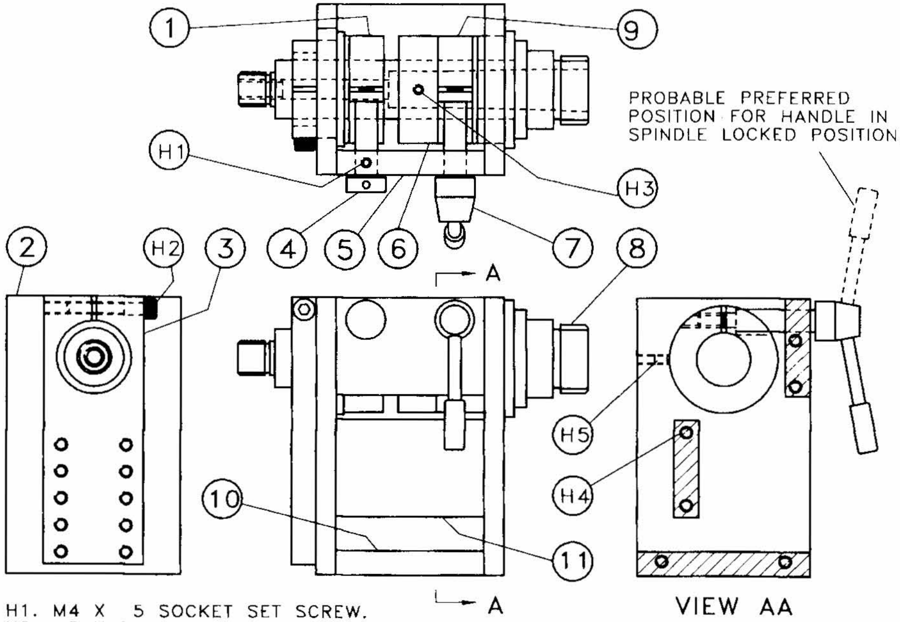
The dividing head featured here is much more advanced than that in the previous chapter, providing three methods of establishing the divisions:
1. Directly off a gear mounted on the dividing head spindle.
2. Directly off a division plate mounted on the dividing head spindle.
3. Interposing a worm and worm wheel between the dividing plate and spindle.

These are based on the same assembly so the constructor can choose to make any or all of the arrangements using the one main frame, **Photo 1**. There would though be little point in constructing method one only as that in the previous chapter is easier to make and more adaptable having the additional gear train. When making the head employing method three, the method one system, (needing only two simple additional items), is well worth providing for its ease of use with simple numbers, 3, 4, 5, 6, etc.

The plate on the left hand side of the assembly (Part 3) can be swung into any position and in **Photo 2** has been fitted with a simple detent mechanism and moved into an easy to operate position. The rows of tapped holes and the slot in the detent carrier (Part 41) enable the arrangement to cope with a wide range of gear diameters. In **Photo 3** a division plate has been fitted and a detent assembly mounted off the arm using the two lower holes. The detent assembly has a slotted lower arm enabling it to function with (different division plate hole circle diameters).

Photo 4 displays the real reason for establishing the design, the inclusion of a worm and wormwheel. Unlike commercial dividing heads, and probably most published designs for home workshop construction, the design is not limited to a single worm/worm wheel ratio. Using 20 DP gears the assembly will cope with a gear up to 65 teeth, limited by the gear hitting the rear of the division plate. The holes in the end plate will though provide sufficient adjustment for gears up to 75 teeth and could be accommodated by increasing the 65mm dimension for Part 8 to 80mm and the length of the spindle (27) accordingly.

Chapter 11 includes tables for the three common dividing head and rotary table worm/worm wheel ratios 40, 60 and 90:1, and fitted with 18 different division plate hole numbers which appear to be the standard. The tables will cover for the



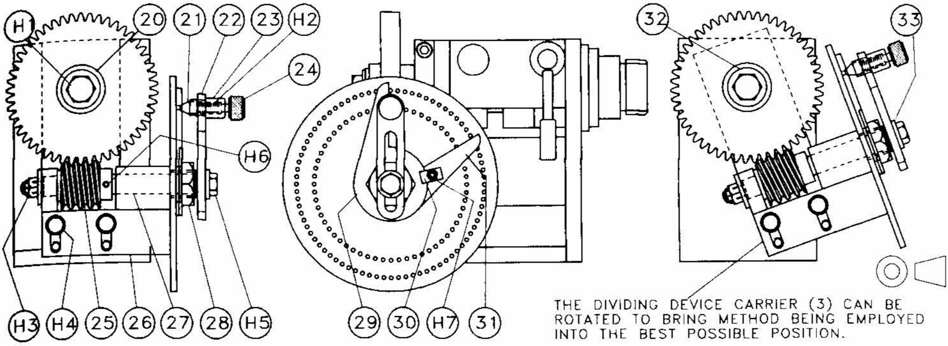
H1. M4 X 5 SOCKET SET SCREW.
H2. M5 X 30 SOCKET CAP SCREW.
H3. M4 X 5 SOCKET SET SCREW 2 OFF.
H4. M5 X 12 SOCKET CAP SCREW 12 OFF.
H5. M4 X 5 SOCKET SET SCREW 2 OFF.

DIVIDING HEAD MAIN ASSEMBLY

dividing head fitted with both 40 and 60 tooth wheels. This still leaves gear sizes of 30, 35, 45, 50, 55, 65, 70, and 75 that will provide additional divisions. However, the majority of the divisions possible with these will also be possible using either a 40 or 60 tooth gear and will be covered by the listing for these. There are though a few that can only be achieved using another gear, typically with a 35 tooth gear, divisions of 77, 91 and 133 are available but not with the 40, 60 and 90:1 ratio dividing heads.

I have run my computer program for each one of the standard changewheel sizes and the 18 division plate numbers and attempted to extricate from the lists produced, those divisions that can only be achieved with this multi-ratio dividing head. This is also included in Chapter 11 though I cannot guarantee that I have not missed an entry or two having had to do this manually.

As designed division plates up to 110mm can be accommodated and as the mounting arrangement can be rotated into any position there is actually no limit in diameter. The limit is as a result of the length of the "detent arm carrier" (54) and

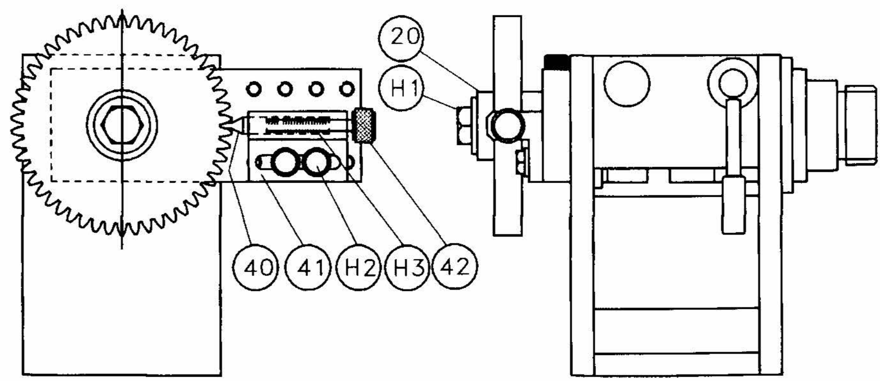


THE DIVIDING DEVICE CARRIER (3) CAN BE ROTATED TO BRING METHOD BEING EMPLOYED INTO THE BEST POSSIBLE POSITION.

H1. M8 X 12 STEEL HEX HEAD SCREW
H2. SPRING
H3. M8 NYLOCK NUT AND STEEL WASHER.
H4. M5 X 16 STEEL HEX HEAD SCREW AND STEEL WASHER. 2 OFF.
H5. M6 X 10 STEEL HEX HEAD SCREW
H6. M3 X 5 SKT SET SCREW. 2 OFF.
H7. M3 X 8 STEEL CSK SCREW AND STEEL NUT.

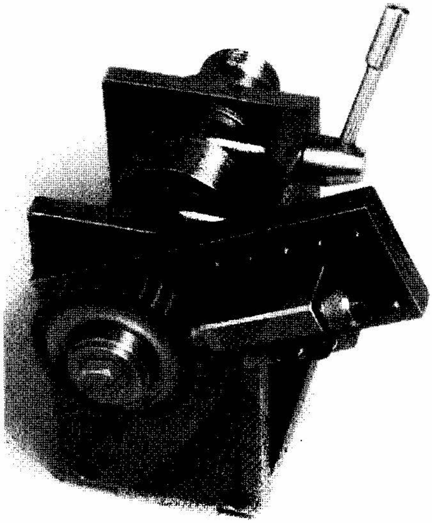
FOR EASE OF DRAWING, THE ANGLE INCLUDED IN ITEM 26 TO SUIT THE HELIX ANGLE OF THE WORM DOES NOT FEATURE IN THIS ASSEMBLY DRAWING. SEE ITEM 26.

WORM AND GEAR ATTACHMENT

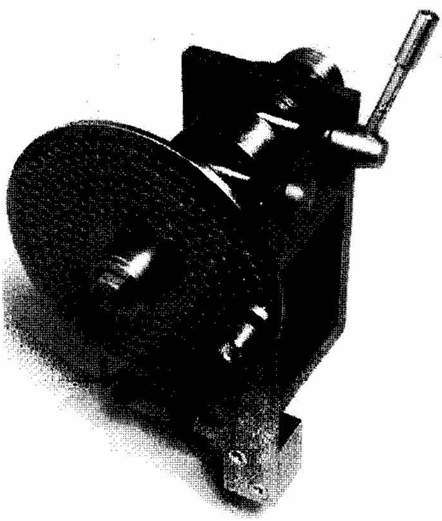


H1. M8 X 12 STEEL HEX HEAD SCREW AND STEEL WASHER.
H2. M5 X 16 STEEL HEX HEAD SCREW AND STEEL WASHER. 2 OFF.
H3. SPRING

GEAR AND DETENT ATTACHMENT



2. *With only the addition of a simple detent assembly, dividing using the lathe's changewheels is possible.*



the "index fingers" (29 and 31) both of which can easily be increased in length when 150mm diameter plates could also be used. The unit in the photos is being used with dividing plates made from sheet steel. These punched plates are made on computer controlled machines and are, even though very economically priced, very accurate. They are 3mm thick but the design should cope with plates up to 6mm thick. It would though be tidier to increase the 14 x 1mm thread on Part 8 to 15mm long and the 79mm dimension on Part 27 to 82mm. Some modification, perhaps a bush, may be, may be needed for differing bore diameters. Incidentally, being punched plates the holes go through whist the commercial thick plates have holes that are blind, surely less easy to keep them clean.

The design is based on being used with a 3 ½in centre height *Myford* Series Seven lathe to enable it to be used with the lathe's tailstock for between centres work. For other centre heights the appropriate dimensions can easily be changed, mounting arrangements may also need changing. In practice, between centres work on the lathe is likely to be of limited, if any, use in many workshops in which case the user may decide to leave the design as published, its real home being on the milling machine.

Manufacture

Materials

The drawings are not specific regarding material specifications but the following will be ideal, being easy to machine. Round items - 230M07 and rectangular parts -

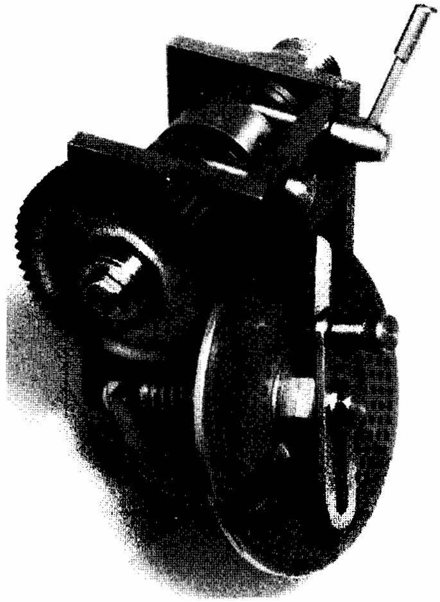
3. *Direct dividing using a division plate and detent assembly added for the purpose.*

070M20 (preferred) or 080A15. 230M07 is free-cutting and is also available in some square bar sizes.

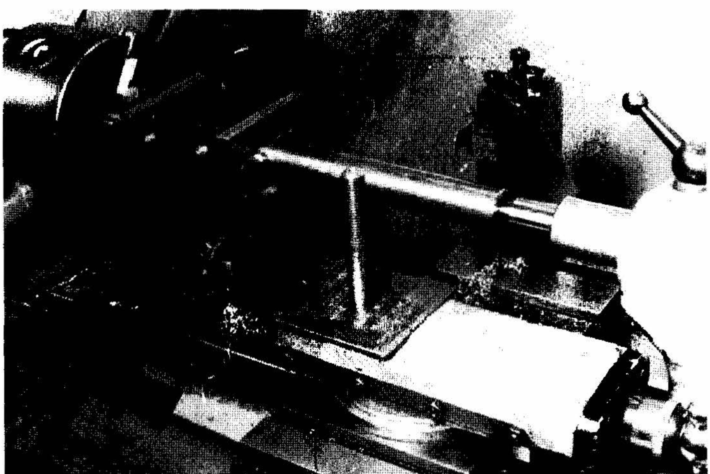
Main assembly

Make the end plates (2) to drawing, except for hole B that should only be 40mm diameter. Assemble together with items 5, 10, 11 and 12, and using item13 mount onto the lathe as shown in **Photo 5**. The boring bar is lightly gripped in the three-jaw chuck, just sufficiently to allow light cuts to be taken but also permitting the tailstock to feed the bar through the end plate to machine the bore. Do not use the tailstock to feed the boring bar through both plates at one pass but do one plate at a time. However, still leave their bores a little undersize, say minus 0.5mm.

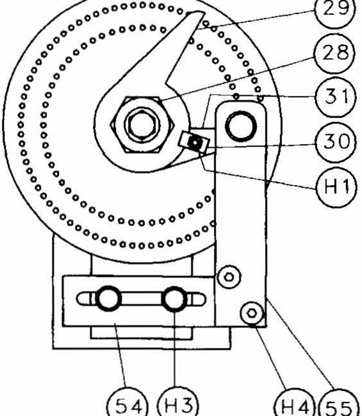
Having bored both ends adjust the boring bar for a final cut, doing first one plate then loosening the chuck moving the bar further into it and then making a final cut on the other plate. Absolute accuracy is not crucial as the bearings can be turned

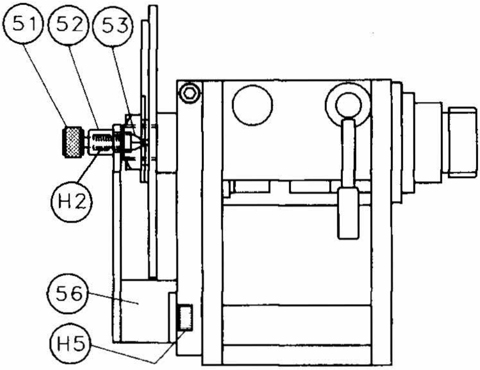


4. The most adaptable version, providing as a result the widest range of possible divisions.



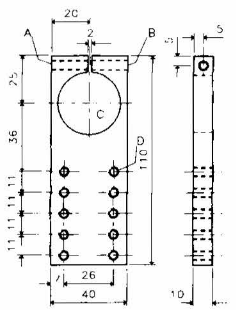
5. The main assembly being bored to take the bearings.





H1. M3 X 6 STEEL CSK SCREW
AND STEEL FULL NUT.
H2. SPRING.
H3. M5 X 12 STEEL HEX HEAD SCREW
AND STEEL WASHER 2 OFF.
H4. M4 X 10 SOCKET CSK SCREW 2 OFF.
H5. M6 X 12 SOCKET CAP SCREW.

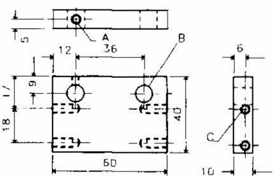
DIVIDING PLATE AND DETENT ATTACHMENT



HOLE SIZES
A. M5 B. 5.5
C. 33 D. M5, 10 OFF

MATL. 40 X 10 MILD STEEL.
QTY. 1 OFF.

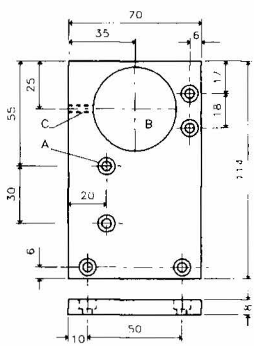
DIVIDING DEVICE CARRIER 3.



HOLE SIZES.
A. M4 B. 9 2 OFF
C. M5 X 10 DEEP 4 OFF

MATL. 40 X 10 MILD STEEL.
QTY. 1 OFF.

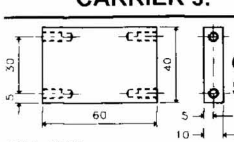
TOP SPACER 5.



HOLE SIZES.
A. 5.5 C.BORE 9dia X 5DEEP 6 OFF.
B. 44
C. M4

MATL. 70 X 8 MILD STEEL.
QTY. 1 OFF AS DRAWN.
1 OFF C/B FROM REVERSE SIDE.

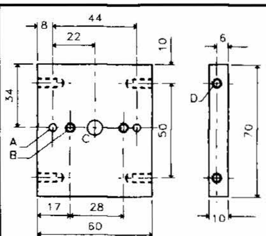
END PLATES 2.



CENTRE SPACER 11.

HOLE SIZES.
M5 X 10 DEEP 4 OFF

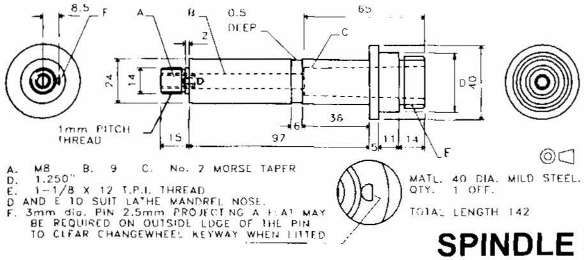
MATL. 40 X 10 MILD STEEL.
QTY. 1 OFF.



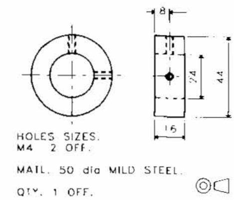
HOLE SIZES.
A. 4 REAM 2 OFF B. M5 2 OFF
C. 8.5 D. M5 X 10 DEEP 4 OFF

MATL. 70 X 10 MILD STEEL.
QTY. 1 OFF.

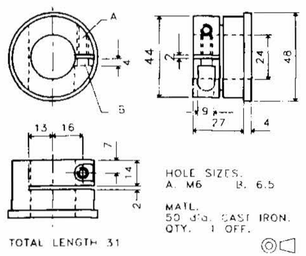
BASE 10.



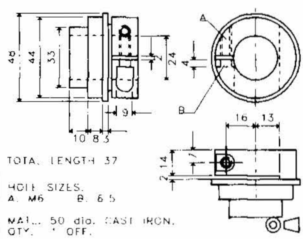
SPINDLE 8.



THRUST COLLAR 6.



FRONT BEARING 9.



REAR BEARING 1.

to fit the bore. The procedure will though ensure both plates are bored to the same size, at centre height and parallel to the unit's base.

Bearings - Parts 1 and 9

Place one piece of cast iron in the three-jaw chuck, face the end and make the bore a little undersize, say minus 0.5mm. Reverse the part in the chuck and face the other end leaving it about 1mm longer than drawing. Repeat for the second bearing.

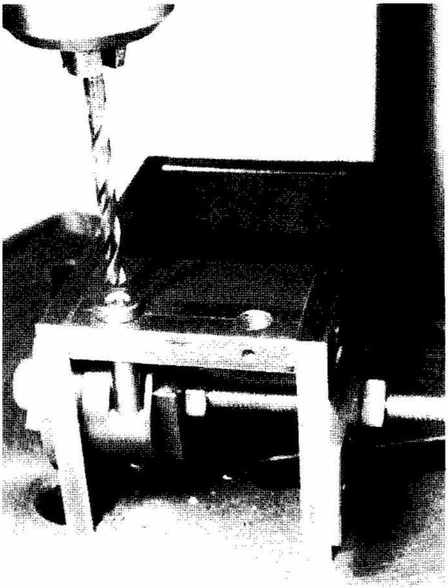
Leave the second part in the chuck and finally bore to size. With the tool still set at that diameter, return the first bearing and bore through at one pass ensuring as a result that both are the same size. This is essential as both are to be machined on the same taper stub mandrel.

Make a taper stub mandrel and fit the first bearing. Machine the outer diameters and both end faces to dimension, doing this using left and right had knife tools and without removing the part from the mandrel. This process ensuring that end faces are square, and the outer diameters concentric, with the bore. Repeat for the other bearing.

Slit, make recess and drill and tap M6. Positioning the hole for tapping is easily done as illustrated in **Photo 6** using the bush detailed in **SK1**.

Spindle - Part 8

Mount a length of material in the three-jaw chuck supporting the outer end with the tailstock centre. Skim a short length of the outer diameter for supporting with a fixed steady. Remove the centre, position fixed steady, refit centre, set steady arms, remove centre and make the 14 x 1mm



6. *Using a bush to position the hole for tapping in the bearings.*

7. *Setting the division plate carrier (26) to 3.5 degrees to suit the helix angle of the worm.*

thread, also drill and tap M8.

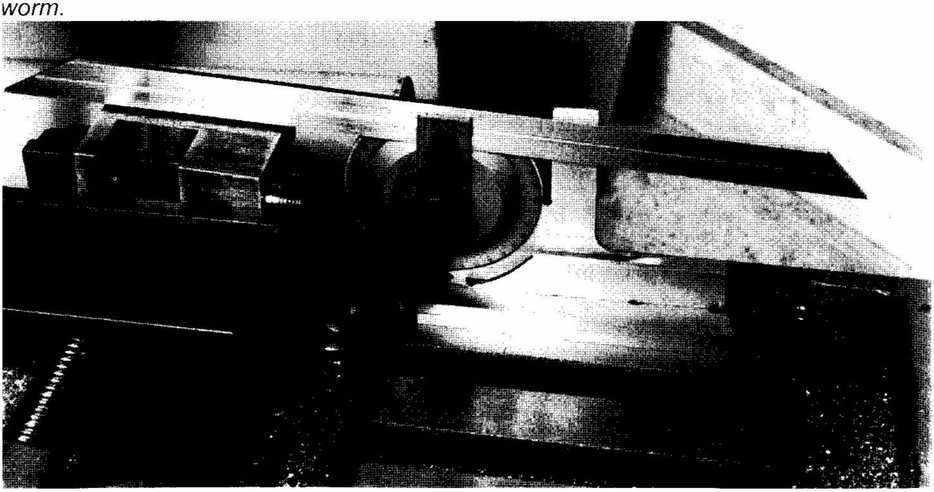
Fit an M8 hex head screw and hold this in the three-jaw again supporting the outer end with a tailstock centre. Check that the turned portion next to the chuck is running reasonably true, if not use the four jaw chuck. In this case file two flats on opposing corners of the hexagon head to take the four jaws. The remainder of the process follows closely that for the spindle in the previous chapter.

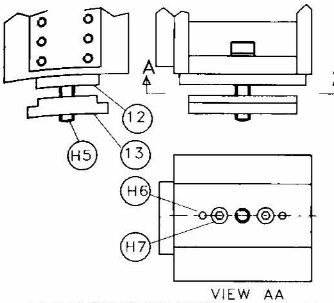
Division plate carrier

This part needs careful planning. However making the part as per stage 1 on the drawings, then creating the 3.5 degree angle, (first one side then the other) and finally the two slots as per stage 2 the process should be relatively easy. **Photo 7** shows the part being set up for machining the first side at 3.5 degrees.

Index fingers parts 29 and 31

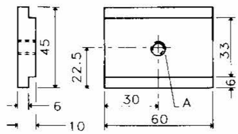
Cut two pieces of 3mm brass, a little oversize, and mark out the position of the 18mm hole. Set up on the lathe faceplate and bore the hole. Follow by boring to





H5. M8 X 35 SOCKET CAP SCREW.
H6. 4 X 15 DOWEL, 2 OFF.
H7. M5 X 12 SOCKET CAP SCREW, 2 OFF.

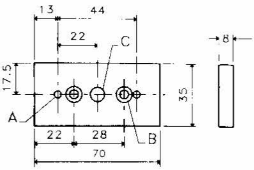
LATHE BED FIXING ASSEMBLY



HOLE SIZE. A. M8

MATL 60 X 10 MILD STEEL.
QTY. 1 OFF.

CLAMP PLATE 13.

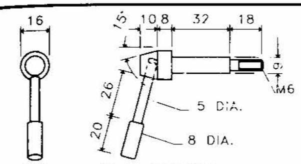


HOLE SIZES.
A. 4 REAM 2 OFF
B. 5.5 C.BORE 9dia. X 5DEEP
C. 8.5

NOTES.
1. HOLES A MUST ALIGN EXACTLY WITH HOLES A IN THE BASE (10)
2. 35 DIMENSION IS A REFERENCE VALUE, MACHINE WIDTH TO BE A CLOSE SLIDING FIT IN LATHE BED.

MATL 70 X 8 MILD STEEL.
QTY. 1 OFF.

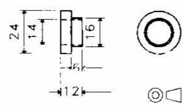
LOCATING PIECE 12.



MATL 16 dia. MILD STEEL.
8 dia. MILD STEEL.
QTY. 1 OFF.

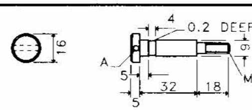
SEE MAIN ASSEMBLY REGARDING BEST POSITION FOR HANDLE ARM.

FRONT BEARING CLAMP HANDLE



MATL 25 dia. MILD STEEL.
QTY. 1 OFF.

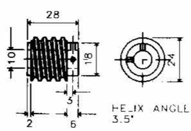
GEAR FIXING COLLAR



HOLE SIZE. A 3.1

MATL. 16 dia. MILD STEEL.
QTY. 1 OFF.

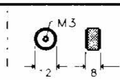
BEARING ADJUSTER 4.



HELIX ANGLE 3.5°

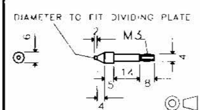
A. M3 2 OFF.
WORM PITCH 6.3662 TPI FOR 20DP GEAR, OR OTHER PITCH TO SUIT GEAR AVAILABLE.

MATL. 25 dia. BRONZE IF AVAILABLE, OTHERWISE MILD STEEL.
QTY. 1 OFF.

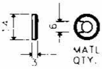


MATL. 12 dia. MILD STEEL.
QTY. 1, 2 OR 3.

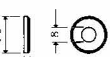
DIAMETER TO FIT DIVIDING PLATE



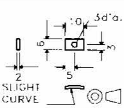
MATL. 6 dia. MILD STEEL.
QTY. 1 OR 2 OFF.



MATL. 15 DIA. MILD STEEL.
QTY. 1 OFF.

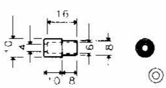


MATL. 20 DIA. MILD STEEL.
QTY. 1 OFF.

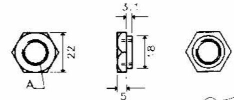


SLIGHT CURVE

MATL. 10 X 2 MILD STEEL.
QTY. 1 OFF.

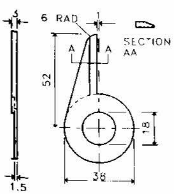


MATL. 10 dia. MILD STEEL.
QTY. 1 OR 2 OFF.

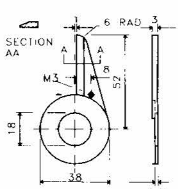


A. THREAD 14 x 1

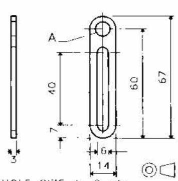
MATL. 22 AF HEX MILD STEEL.
QTY. 1 OFF.



MATL. 3 THICK BRASS.
QTY. 1 OFF.



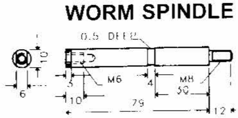
MATL. 3 THICK BRASS.
QTY. 1 OFF.



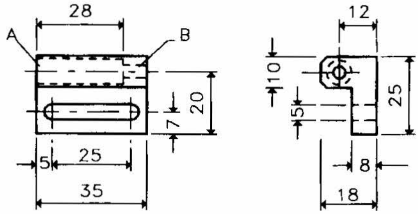
HOLE SIZE A. 8 dia.

MATL. 15 X 3 MILD STEEL.
QTY. 1 OFF.

WORM SPINDLE 27.



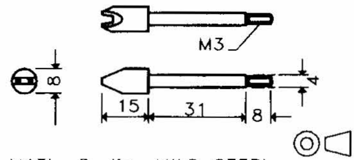
MATL. 10 dia. MILD STEEL.
QTY. 1 OFF.



HOLE SIZES. A. 8 B. 4.1

MATL. 35 X 25 MILD STEEL.
QTY. 1 OFF.

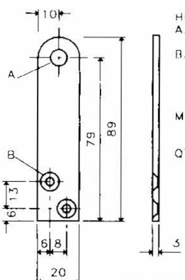
DETENT CARRIER 41.



MATL. 8 dia. MILD STEEL.
QTY. 1 OFF.

SHAPE END TO SUIT GEAR BEING USED. THE FORKED END PERMITS THE DETENT, IF ROTATED 90°, TO LOCATE ON ONE TOOTH AS WELL AS BETWEEN TWO TEETH. THIS DOUBLES THE NUMBER OF DIVISIONS OBTAINED WITH A GIVEN GEAR.

DETENT 40.

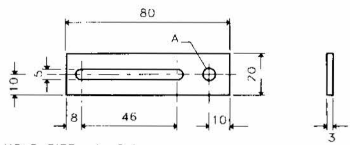


HOLE SIZES.
A. 8
B. 4
CSK
90° X 8 dia.
2 OFF.

MATL. 20 X 3
MILD STEEL.

QTY. 1 OFF.

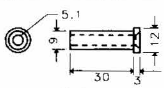
DETENT ARM 55.



HOLE SIZE A. 6.1

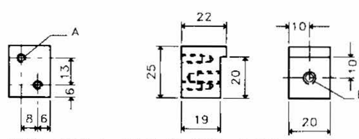
MATL. 20 X 3 MILD STEEL. QTY. 1 OFF.

DETENT ARM CARRIER 54.



MATL. 12 DIA. MILD STEEL.
QTY. 1 OFF.

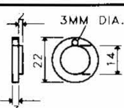
BEARING DRILLING BUSH SK1



HOLE SIZES A. M4 X 10 DEEP. 2 OFF.
B. M6 X 12 DEEP.

MATL. 25 X 25 MILD STEEL. QTY. 1 OFF.

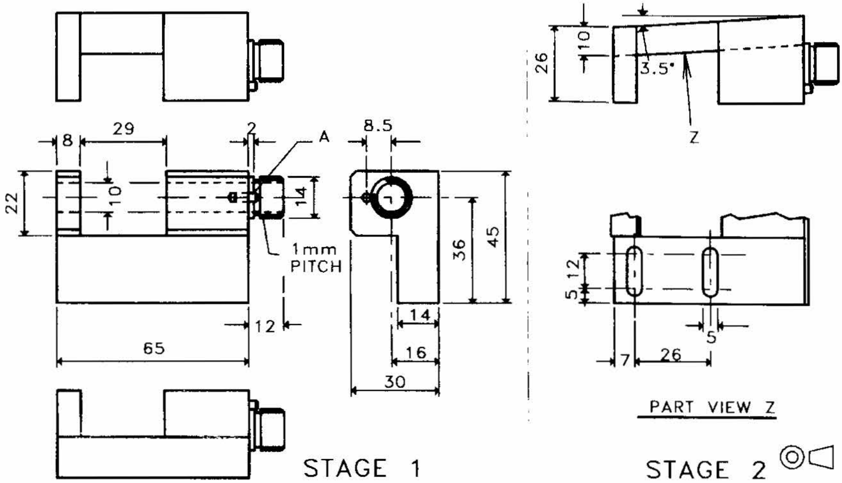
DETENT ARM PACKING 56.



3MM DIA. MATL. 22 DIA.
MILD STEEL.

QTY. 1 OFF.

DIVIDING PLATE DRILLING JIG SK2



MATL. 45 X 30 MILD STEEL. QTY. 1 OFF.

A. 3mm dia. PIN 2.5mm PROJECTION. MAY REQUIRE FLAT SEE SPINDLE PART 8.

DIVISION PLATE CARRIER 26.

38mm diameter and 1.6mm deep. Repeat for second part. Mark out outlines and cut roughly to size, then carefully file to profile. The 38mm diameter counterbore giving the outline of the part in that area.

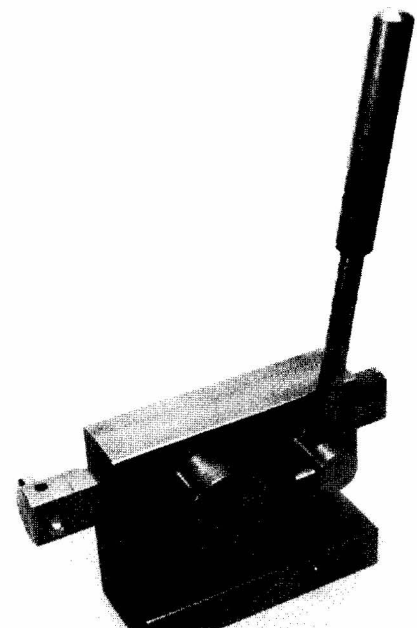
Division plate nut Part 28

This is a straightforward item to make but, when assembled, must clamp the fingers so that they can be moved, but only with some resistance. If easy to move then they may move whilst traversing the detent from one hole to another. To achieve the required action, dish the front finger to give the effect of a disc spring. Form this by clamping the finger in the vice, backed by a piece of soft wood and with a piece of 22mm diameter steel placed centrally over the hole. Tighten the vice very slightly to form a dish just sufficient to provide adequate friction.

The remaining parts should not present any problem. When assembled you will be in possession of a quality dividing head, very robust, and able to provide more divisions that a commercial semi universal dividing head. You will also have the satisfaction of having made the item.

Chapter 9

Shop-made Lining Tool

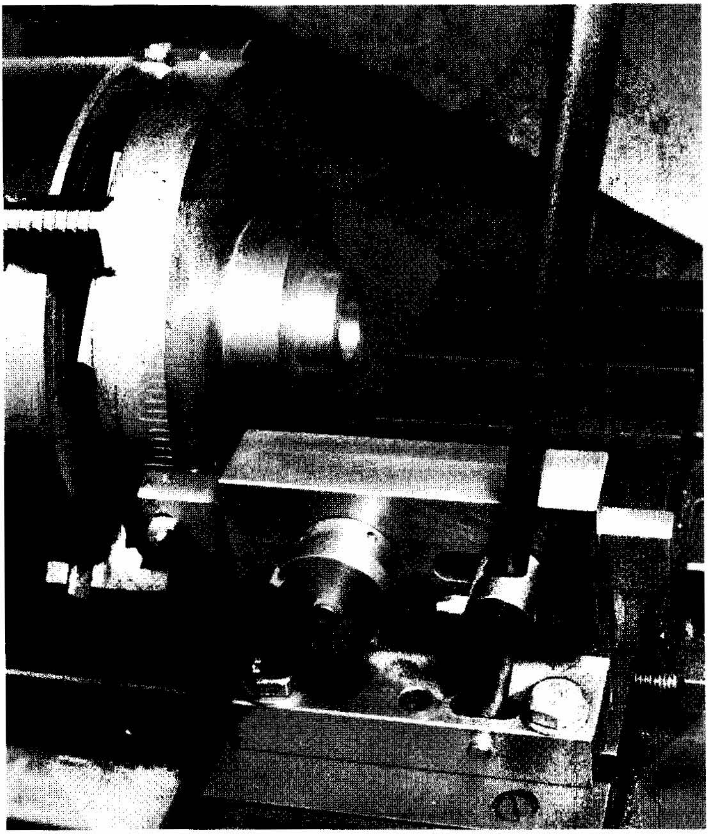


1. The Lining device, note the recesses in the disc to achieve the differing line lengths.

The item in this chapter is not used for dividing and as such is out of place in this book. It is though a lining tool for engraving dials and therefore used where dividing is very much a part of the task being carried out. Also to my knowledge it is not an item that is available commercially and has therefore to be made in the workshop.

The purpose of the tool, **Photo 1**, is to enable lines on a dial to be made to set lengths and automatically in the order required. Typically for an imperial leadscrew dial the sequence would be, one long (tens), four short (units), one medium length (fives) and four short (units), repeating as required.

The differences in line lengths are controlled by the stop disc (4) this is not adjustable but being such a simple item, others can easily be made as required. The sequence is controlled by a ratchet wheel (12) and pawl (11). The ratchet wheel as drawn has ten teeth limiting repeat sequences to 2, 5 or 10. Should another sequence be required a second ratchet wheel would have to be fitted. Whilst internal, changing the wheel is not a large task. Typical of such a requirement would be calibrate a metric dial in divisions of

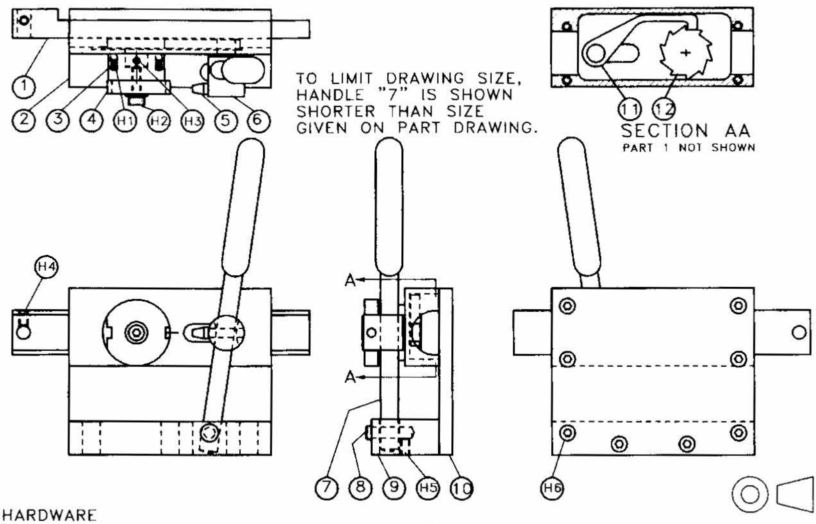


2. The device mounted on the lathes cross slide.

0.025 mm making it very close to 0.001". This would need a ratchet having 8 teeth and giving, one long (0.1 mm) three short (0.025 mm), one long (0.1 mm) and three short (0.025 mm).

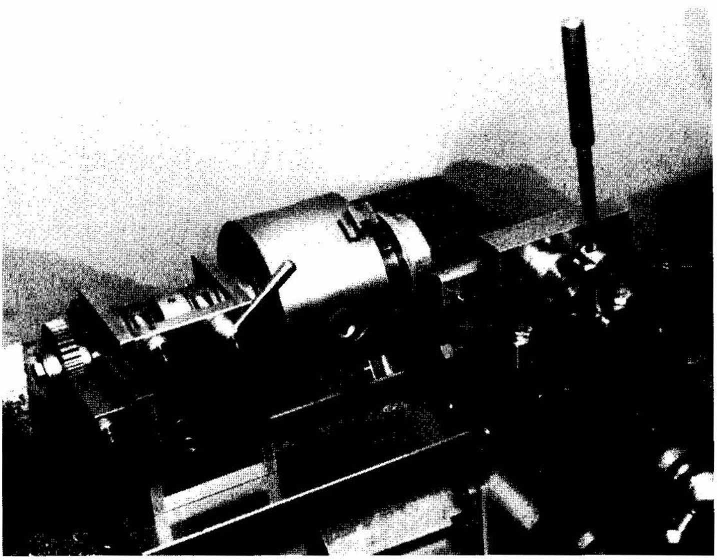
The unit would normally be used on the lathes cross slide with the top slide removed as seen in **Photo 2**. The position of the lathe's saddle would be set and locked to give the line lengths required and the cross slide set to give the depth of cut. In use the tool is much easier than using the top slide with the need to control line lengths by observing its leadscrew dial readings and having to count the number of lines made of each length. **Photo 3** shows it being used in conjunction with the basic assembly of the dividing head in the previous chapter mounted on the lathe's bed.

Ideally the cutting tool should be nominally at the lathes centre height, it may therefore be necessary to change the 40 mm and 72 mm dimensions of the angle upright (10) to suit the lathe on which it is to be used. In this respect the dimensions

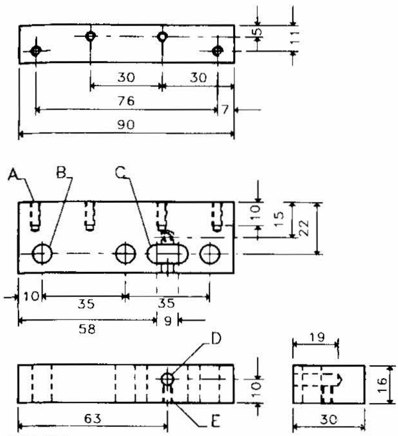


HARDWARE
H1. 4mm DIA, STEEL BALL AND SHORT COMPRESSION SPRING. 2 OFF.
H2. M4 X 10 SOCKET HEAD CAP SCREW. 1 OFF.
H3. M3 X 6 SOCKET GRUB SCREW. 2 OFF.
H4. M4 X 6 SOCKET GRUB SCREW. 1 OFF.
H5. M4 X 6 SOCKET GRUB SCREW. 1 OFF.
H6. M4 X 10 SOCKET HEAD CAP SCREW. 8 OFF.

LINING TOOL ASSEMBLY



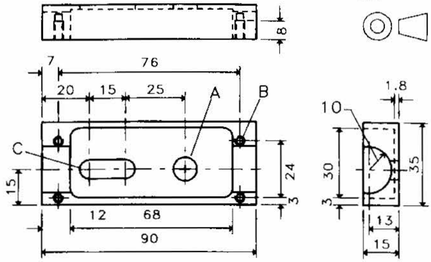
3. Being used to engrave a milling machine leadscrew dial. This is using the dividing head from the previous chapter.



HOLES.
A. M4. B. 8.1
C. 8 WIDE SLOT. D. 5
E. M4.

MATL. 30 X 16 STEEL 070M20.
QTY. 1 OFF

ANGLE BASE 9.

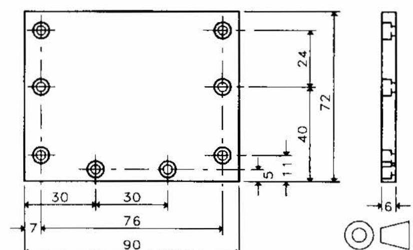


HOLES.
A. 10 B. M4. 4 OFF. C. 9 WIDE SLOT

MATL. 35 X 16 STEEL 070M20 QTY. 1 OFF.

NOTE. REDUCE TO 15 THICK WITH ITEM 1 FITTED IN PLACE. AS A RESULT MACHINING THE FLAT ON ITEM 1 AT THE SAME TIME.

SLIDE BODY 2.



HOLES. 4.4, CB 7.5 X 4 DEEP. 8 OFF.

MATL. 90 X 6, OR 75 X 6 STEEL 070M20.
QTY. 1 OFF.

ANGLE UPRIGHT 10.

given have been established to suit a Myford Series Seven.

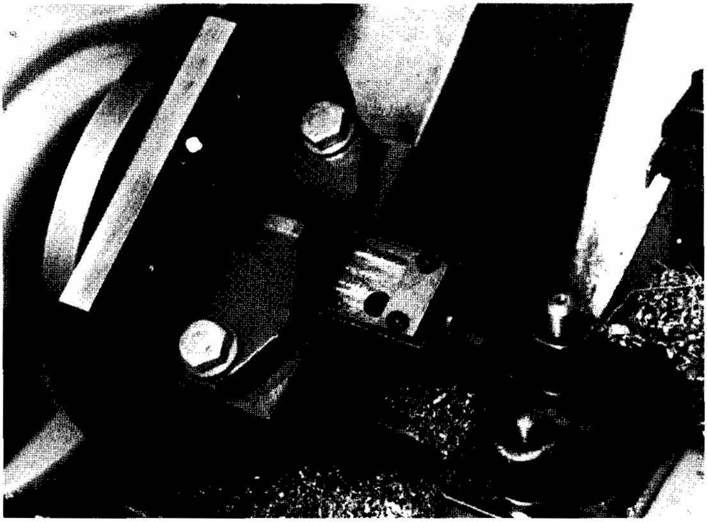
Manufacture

Once more I will only comment on those aspects of manufacture that warrant it. The main consideration when making the various parts is to ensure that the slide moves without perceptible shake. This is the reason for the flat on the second side of the slide (1) ensuring that the slide mates with slide body (2) on its sides. Otherwise, any clearance between their two diameters would result in the parts mating only in the bottom of the semi circular portion of the slide body.

Another feature for which the reason is not obvious is the 12 mm x 1 mm deep cut out on the slide. This ensures that any slight sideways movement at the end of the pawl does not result in it catching on the slide and preventing it engaging with the ratchet wheel.

The slide assembly

Place a length of 22 mm diameter steel in the chuck, support by the tailstock centre and reduce to 20 mm checking to ensure that it is being turned parallel. Adjust the

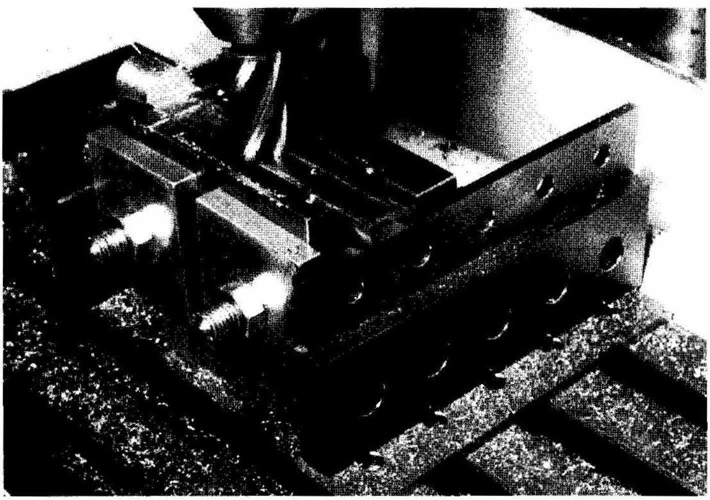


4. Boring the ends of the slide body (2)

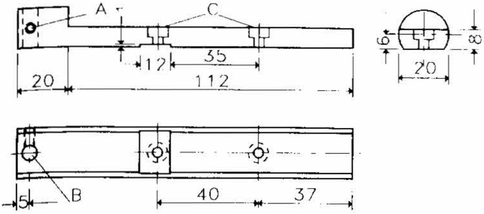
tailstock set over if required.

Next, cut a length of material for the slide body and machine it to length, the thickness being left at 16 mm at this stage, machine the recess and slot C also holes A, B.

Carefully mark both ends of the body with the centre position of the 10 mm radius and centre punch. Mount the slide body on the face plate using an angle plate, or a Keats angle plate, as in **Photo 4**, and using a centre finder to accurately position the



5. Milling the second flat on the slide (1)

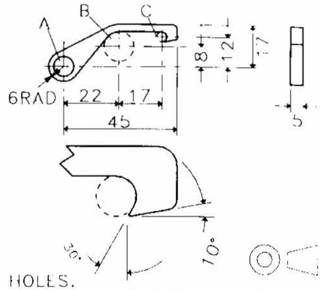


HOLES. A. M4 B. 6. SEE NOTE.
C. 4.4 CB 7.5 X 4 DEEP. SEE NOTE.

NOTES.
1. DRILL HOLE B AFTER ASSEMBLY AND WHILST FITTED TO THE LATHE SO AS TO ENSURE HOLE IS AT CENTRE HEIGHT.
2. LEFT HAND HOLE C IS FOR USE FOR HOLDING THE PART TOGETHER WITH ITEM 2 WHEN MACHINING THE TWO PARTS SIMULTANEOUSLY. NOT USED FOR FINAL ASSEMBLY.

MATL. 20 DIA. STEEL 230M07.
QTY. 1 OFF.

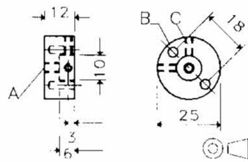
SLIDE 1.



HOLES.
A. 8.2 B. 12 C. 4

MATL. 5 THICK STEEL 070M20.
QTY. 1 OFF.

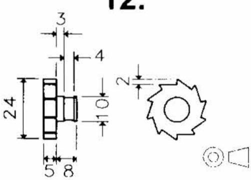
PAWL 11.



HOLES A. M4
B. 4.1 10 DEEP. C. M3
MATL.
25 DIA. STEEL 230M07.
QTY. 1 OFF.

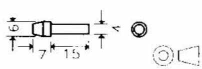
STOP DISC CARRIER 3.

RATCHET WHEEL 12.



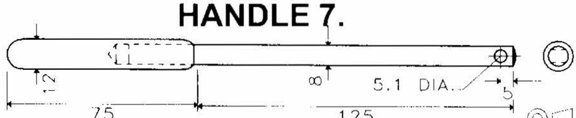
MATL.
25 DIA. STEEL 230M07
QTY. 1 OFF.

STOP PIN 5.



MATL.
6 DIA. STEEL 230M07
QTY 1 OFF.

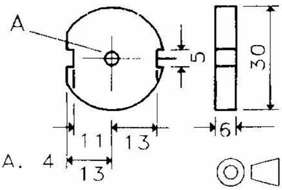
HANDLE 7.



MATL. 12 DIA. AND 8 DIA. STEEL 230M07.
QTY. 1 OFF.

part for boring. Cut two small pieces of steel and drill to fit across holes B at either end. These allow each end to be bored 20 mm diameter as a continuous rather than an intermittent cut. Bore the slide recess in one end as shown in the photograph to be a close fit on the slide. Remove, reverse and repeat the operation on the other end. However, if you have a suitable angle plate, rather than the Keats, and a long boring tool it would be better to machine both ends without removing the part. This would guarantee alignment.

Next mill the first flat on the slide - the one that passes along the whole length of the part. It is essential that this is the same depth along the length or else the part will get wider along its length causing it to be loose at one end of its movement. With this in mind, hold the part in a vice and with each end supported by precision parallels. Take a very light cut of about 0.05 mm deep

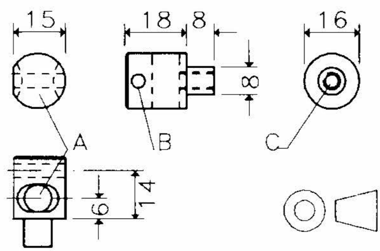


HOLE. A. 4

MATL. 30 DIA STEEL 230M07
QTY. 1 OFF

THIS GIVES LINE LENGTHS OF +2 AND +4. MAKE EXTRA DISCS FOR OTHER LINE LENGTHS.

STOP DISC 4.

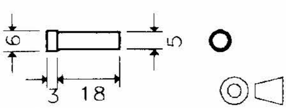


HOLES.
A. 8.5. BELLMOUTH SIDEWAYS ONLY TO ALLOW FOR MOVEMENT OF HANDLE.
B. 4
C. M4

MATL. 16 DIA. STEEL 230M07.
QTY 1 OFF.

SLIDE OPERATING POST 6.

HINGE PIN 8.



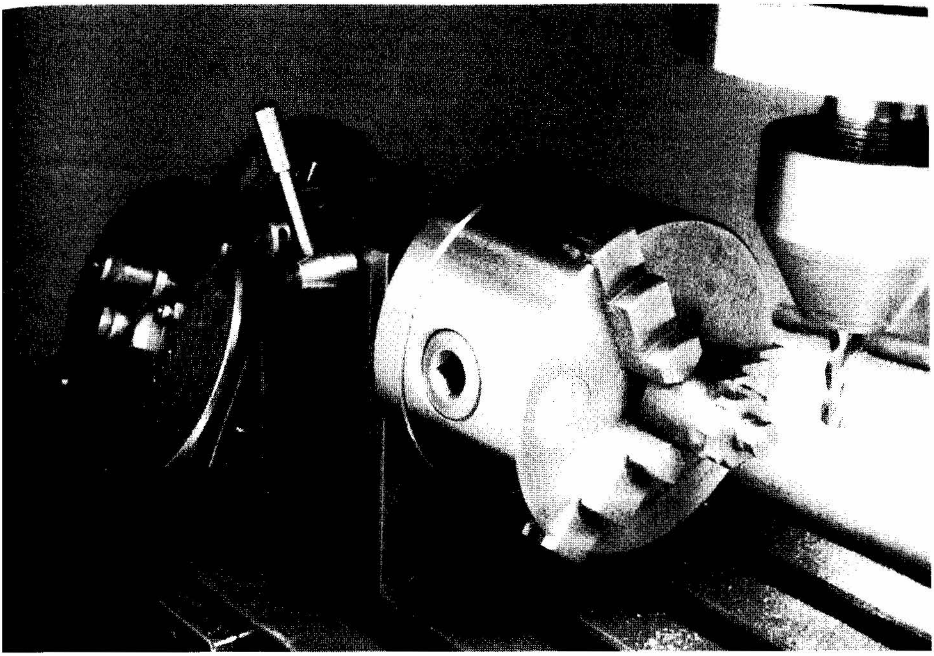
MATL.
6 DIA. STEEL 230M07
QTY 1 OFF.

along the length to check if all is well. Any error will be obvious in the varying width of the flat produced.

Drill and counterbore holes C, and use these to fix the part to the slide body for machining the second flat. Again support the ends on parallels and machine both slide and body to achieve the 15 mm dimension doing this as in **Photo 5**.

The remaining parts

These are all straight forward and need no comment other than to say the ratchet will be a good first item to produce using either of the dividing heads in the previous chapters, see **Photo 6**. The part was first turned on the lathe, then moved to the milling machine still in the three jaw chuck and the ratchet machined as shown. It was then returned to the lathe and parted off from the stub in the chuck. Finally held on the smaller diameter and the parted face finally machined to achieve the required thickness for the ratchet.



6. Machining an eight tooth ratchet wheel.

Chapter 10

Prime Numbers

The reader may ask, what are prime numbers and what is their relevance to the subject of this book?

Taking prime numbers first. These are numbers which are only divisible by 1 and itself; typically, 1, 2, 3, 5, 7, 11, 13, and on up to infinity. There are therefore very many and even a very advanced mathematician will be unable to recognise beyond values of a hundred or so. For this reason tables of prime numbers are an essential requirement when dealing with such numbers.

Prime factors

These are those prime numbers that when multiplied together give the number being considered. For example, prime factors of 105 are 3, 5, and 7.

3x5x7 = 105

The method of arriving at these from a list of prime numbers is as follows

1. Is the number even? No therefore start using the tables.
2. Look up 105 and the smallest factor is 3.
3. Divide by 3 to give 35.
4. Look up 35 and the smallest factor is 5.
5. Divide by 5 to give 7.
6. Look up 7 which is found to be a prime number.
7. The prime factors are therefore 3, 5 and 7.

Prime factors of an even number

For this find the prime factors of 132.

1. Being an even number the smallest factor is 2.
2. Divide 132 by 2 to give 66, again an even number.
3. Divide 66 by 2 to give 33.
4. 33 is an odd number
5. Look up 33 and the smallest factor is 3
6. Divide 33 by 3 to give 11.
7. Look up 11 which is found to be a prime number.
8. The prime factors are therefore 2, 2, 3 and 11.

2x2x3x11 = 132

Both these examples are simple and prime factors could easily be established without the aid tables.

However, consider finding the factors of 1927. This, it will be found, is not divisible by 3, 5, 7, 11, 13, nor 17, etc. Its lowest prime factor is in fact 41. Dividing 1927 by

41 will give 47 also found to be a prime number. The prime factors therefore 41x49 = 1927. Obviously a time consuming task without the aid of the tables.

Unfortunately though, space limitations in this book restrict the table to 2000. To minimise the task of finding prime numbers above this a list of prime numbers up to 10,000 is also included. This will avoid looking for the prime factors of a number which is in itself a prime number, typically, 4933.

Numbers greater than 2000

First take note that no number in the range 2000 to 10000 has a prime factor greater than 97, that is 24 possibilities. In this range therefore take the following approach:

First, if even, divide by 2, if not try 3, 5, 7, 11 etc. until the lowest prime factor is found. Having found this, divide the number by this value and in most cases the result will then be below 2000 and the table can then be used. If not, repeat after first checking to see that it is not a prime number.

The procedure is unlikely to be as time consuming as may first be thought as every third number is divisible by three, every fifth number by five, every seventh number by seven and so on. As a result most numbers have a low first prime factor.

What use are Prime numbers?

How then will this be of use when dividing? Well, you may have acquired a second hand dividing head without its manual, or purchased an additional plate not on your manual's list, in these cases you will have to resort to calculations.

Consider a division plate having a ring with 49 holes. If this is used with a head having a worm/worm wheel ratio of 40:1 then for 1 turn at the output 40x49 holes on the plate will be passed, that is 1960. As explained in earlier chapters any number that divides exactly into this will be a possible division. To easily arrive at values possible if will be necessary to find its prime numbers as explained above. Dividing by 2, 2, 2, 5, 7, 7 giving 980, 490, 245, 49, 7, 1.

The result will be 2, 2, 2, 5, 7, 7. which are of course, numbers of holes and must be divided into 1960 to determine the division possible. Ignoring the higher numbers possible as they are unlikely to have a practical use, the more useful values are typically.

1960/2x7=140
1960/2x2x5=98
1960/2x2x7=70
1960/5x7=56
1960/7x7=40
1960/2x5x7=28

I have also ignored the lower numbers, such as 1960/2x2x5x7 = 14 as these are bound to be achievable by an easier route. As already mentioned the prime factors relate to the number of holes traversed, therefore for 28 divisions the number of holes traversed will be 2x5x7 = 70. As the division plate being used has a ring of 49 holes, this will be achieved with 1 turn plus 21 holes.

Some readers will I am sure have noticed that the prime factors 2, 2, 2, 5, 7 and 7 are in fact the prime factors of the two initial values, 40 (2x2x2x5) and 49 (7x7). However, I have presented the explanation in this form as when working with the three gear dividing head in Chapter 7 the ratio may not be a simple one, say 60:1, but with gears of 45 and 35 the ratio

will be 9:7. In this situation it will be easier to work with the number of holes passed which in some cases will be with more than one revolution of the workpiece, as explained in Chapter 4 Example 3.

Having provided the list of prime numbers I have decided to include briefly some details on another and more demanding use for them. This is establishing gear sizes for complex ratios, it may of course create a need to use your dividing facilities for making a specific size gear.

Designing gear chains

A typical use for prime factor tables is in the design of gear chains requiring complex ratios, such as when determining change wheel combinations for cutting Metric threads on a lathe with an imperial leadscrew, and visa versa. Also when cutting worm wheels which similarly require complex ratios.

Example

If requiring to cut a thread with a pitch of lmm on a lathe having an 8 TPI leadscrew the lathe's mandrel will have to rotate 25.4 times whilst the leadscrew rotates 8 times. This therefore requires a ratio of 25.4 : 8.

Expressing this as a fraction we get:

$$\frac{8}{25.4} = \frac{1}{.314960629}$$

Accepting that an exact ratio will not be possible, this can be simplified to

$$\frac{1}{.315}$$

As decimals are not appropriate to fractions this must be written as

$$\frac{1000}{315}$$

That is multiplying both top and bottom by 1000.

Factorising both 1000 and 315, using the tables, we get

$$\frac{2x2x2x5x5x5}{3x3x5x7}$$

Cancelling out one 5 we get

$$\frac{2x2x2x5x5}{3x3x7}$$

Ignoring the fact that gears cannot be made with so few teeth, we still have a problem as there are 5 driven gears but only 3 drivers. If we multiply 2x2 and 2x5 we get 3 drivers and 3 driven as follows

$$\frac{4x10x5}{3x3x7}$$

Multiplying each number by 10 will give practical gear sizes and being in 10's are likely to be available with the lathe. We get

$$\frac{40x100x50}{30x30x70}$$

A 100 tooth gear is unlikely to be available so reducing this to 50 and the 70 to 35 will retain the ratio.

$$\frac{40x50x50}{30x30x35}$$

The combination now requires two 30 and two 50 tooth gears, but, increasing one of each by a factor of 1.5 they become 45 and 75 tooth gears, again retaining the ratio. The resulting gear chain becomes:

$$\frac{40x75x50}{30x45x35}$$

This gives a TPI

$$8 \times \frac{40 \times 50 \times 75}{30 \times 35 \times 45} = 25.3968254$$

Pitch in millimetres is very close at

$$\frac{25.4}{25.3968254} = 1.000125\text{mm}$$

At 25 pitches this is a total error of plus 0.003125 mm or if you are imperially inclined 0.000123in in practice a negligible amount.

This can be simplified by dividing 50 by 10 and 5, 30 by 10 and 35 by 5 to give

$$8 \times \frac{40 \times 1 \times 75}{3 \times 7 \times 45}$$

simplified giving

$$8 \times \frac{40 \times 75}{21 \times 45} = 25.3968254$$

This will be easier to set up using only two drivers and two driven but requires a 21 tooth gear that will be special for most changewheel sets.

PRIME NUMBER AND SMALLEST FACTOR TABLE

	1 up	101 up	201 up	301 up	401 up	501 up	601 up	701 up	801 up	901 up
1	P	P	3	7	P	3	P	P	3	17
3	P	P	7	3	13	P	3	19	11	3
5	P	3	5	5	3	5	5	3	5	5
7	P	P	3	P	11	3	P	7	3	P
9	3	P	11	3	P	P	3	P	P	3
11	P	3	P	P	3	7	13	3	P	P
13	P	P	3	P	7	3	P	23	3	11
15	3	5	5	3	5	5	3	5	5	3
17	P	3	7	P	3	11	P	3	19	7
19	P	7	3	11	P	3	P	P	3	P
21	3	11	13	3	P	P	3	7	P	3
23	P	3	P	17	3	P	7	3	P	13
25	5	5	3	5	5	3	5	5	3	5
27	3	P	P	3	7	17	3	P	P	3
29	P	3	P	7	3	23	17	3	P	P
31	P	P	3	P	P	3	P	17	3	7
33	3	7	P	3	P	13	3	P	7	3
35	5	3	5	5	3	5	5	3	5	5
37	P	P	3	P	19	3	7	11	3	P
39	3	P	P	3	P	7	3	P	P	3
41	P	3	P	11	3	P	P	3	29	P
43	P	11	3	7	P	3	P	P	3	23
45	3	5	5	3	5	5	3	5	5	3
47	P	3	13	P	3	P	P	3	7	P
49	7	P	3	P	P	3	11	7	3	13

PRIME NUMBER AND SMALLEST FACTOR TABLE

	51 up	151 up	251 up	351 up	451 up	551 up	651 up	751 up	851 up	951 up
51	3	P	P	3	11	19	3	P	23	3
53	P	3	11	P	3	7	P	3	P	P
55	5	5	3	5	5	3	5	5	3	5
57	3	P	P	3	P	P	3	P	P	3
59	P	3	7	P	3	13	P	3	P	7
61	P	7	3	19	P	3	P	P	3	31
63	3	P	P	3	P	P	3	7	P	3
65	5	3	5	5	3	5	5	3	5	5
67	P	P	3	P	P	3	23	13	3	P
69	3	13	P	3	7	P	3	P	11	3
71	P	3	P	7	3	P	11	3	13	P
73	P	P	3	P	11	3	P	P	3	7
75	3	5	5	3	5	5	3	5	5	3
77	7	3	P	13	3	P	P	3	P	P
79	P	P	3	P	P	3	7	19	3	11
81	3	P	P	3	13	7	3	11	P	3
83	P	3	P	P	3	11	P	3	P	P
85	5	5	3	5	5	3	5	5	3	5
87	3	11	7	3	P	P	3	P	P	3
89	P	3	17	P	3	19	13	3	7	23
91	7	P	3	17	P	3	P	7	3	P
93	3	P	P	3	17	P	3	13	19	3
95	5	3	5	5	3	5	5	3	5	5
97	P	P	3	P	7	3	17	P	3	P
99	3	P	13	3	P	P	3	17	29	3

PRIME NUMBER AND SMALLEST FACTOR TABLE

	1001 up	1101 up	1201 up	1301 up	1401 up	1501 up	1601 up	1701 up	1801 up	1901 up
1	7	3	P	P	3	19	P	3	P	P
3	17	P	3	P	23	3	7	13	3	11
5	3	5	5	3	5	5	3	5	5	3
7	19	3	17	P	3	11	P	3	13	P
9	P	P	3	7	P	3	P	P	3	23
11	3	11	7	3	17	P	3	29	P	3
13	P	3	P	13	3	17	P	3	7	P
15	5	5	3	5	5	3	5	5	3	5
17	3	P	P	3	13	37	3	17	23	3
19	P	3	23	P	3	7	P	3	17	19
21	P	19	3	P	7	3	P	P	3	17
23	3	P	P	3	P	P	3	P	P	3
25	5	3	5	5	3	5	5	3	5	5
27	13	7	3	P	P	3	P	11	3	41
29	3	P	P	3	P	11	3	7	31	3
31	P	3	P	11	3	P	7	3	P	P
33	P	11	3	31	P	3	23	P	3	P
35	3	5	5	3	5	5	3	5	5	3
37	17	3	P	7	3	29	P	3	11	13
39	P	17	3	13	P	3	11	37	3	7
41	3	7	17	3	11	23	3	P	7	3
43	7	3	11	17	3	P	31	3	19	29
45	5	5	3	5	5	3	5	5	3	5
47	3	31	29	3	P	7	3	P	P	3
49	P	3	P	19	3	P	17	3	43	P

PRIME NUMBER AND SMALLEST FACTOR TABLE

	1051 up	1151 up	1251 up	1351 up	1451 up	1551 up	1651 up	1751 up	1851 up	1951 up
51	P	P	3	7	P	3	13	17	3	P
53	3	P	7	3	P	P	3	P	17	3
55	5	3	5	5	3	5	5	3	5	5
57	7	13	3	23	31	3	P	7	3	19
59	3	19	P	3	P	P	3	P	11	3
61	P	3	13	P	3	7	11	3	P	37
63	P	P	3	29	7	3	P	41	3	13
65	3	5	5	3	5	5	3	5	5	3
67	11	3	7	P	3	P	P	3	P	7
69	P	7	3	37	13	3	P	29	3	11
71	3	P	31	3	P	P	3	7	P	3
73	29	3	19	P	3	11	7	3	P	P
75	5	5	3	5	5	3	5	5	3	5
77	3	11	P	3	7	19	3	P	P	3
79	13	3	P	7	3	P	23	3	P	P
81	23	P	3	P	P	3	41	13	3	7
83	3	7	P	3	P	P	3	P	7	3
85	5	3	5	5	3	5	5	3	5	5
87	P	P	3	19	P	3	7	P	3	P
89	3	29	P	3	P	7	3	P	P	3
91	P	3	P	13	3	37	19	3	31	11
93	P	P	3	7	P	3	P	11	3	P
95	3	5	5	3	5	5	3	5	5	3
97	P	3	P	11	3	P	P	3	7	P
99	7	11	3	P	P	3	P	7	3	P

PRIME NUMBERS FROM 2000 TO 4999

2003 11 17 27 29 39 53 63 69 81 83 87 89 99
2111 13 29 31 37 41 43 53 61 79
2203 07 13 21 37 39 43 51 67 69 73 81 87 93 97
2309 11 33 39 41 47 51 57 71 77 81 83 89 93 99
2411 17 23 37 41 47 59 67 73 77

2503 21 31 39 43 49 51 57 79 91 93
2609 17 21 33 47 57 59 63 71 77 83 87 89 93 99
2707 11 13 19 29 31 41 49 53 67 77 89 91 97
2801 03 19 33 37 43 51 57 61 79 87 97
2903 09 17 27 39 53 57 63 69 71 99

3001 11 19 23 37 41 49 61 67 79 83 89
3109 19 21 37 63 67 69 81 87 91
3203 09 17 21 29 51 53 57 59 71 99
3301 07 13 19 23 29 31 43 47 59 61 71 73 89 91
3407 13 33 49 57 61 63 67 69 91 99

3511 17 27 29 33 39 41 47 57 59 71 81 83 93
3607 13 17 23 31 37 43 59 71 73 77 91 97
3701 09 19 27 33 39 61 67 69 79 93 97
3803 21 23 33 47 51 53 63 77 81 89
3907 11 17 19 23 29 31 43 47 67 89

4001 03 07 13 19 21 27 49 51 57 73 79 91 93 99
4111 27 29 33 39 53 57 59 77
4201 11 17 19 29 31 41 43 53 59 61 71 73 83 89 97
4327 37 39 49 57 63 73 91 97
4409 21 23 41 47 51 57 63 81 83 93

4507 13 17 19 23 47 49 61 67 83 91 97
4603 21 37 39 43 49 51 57 63 73 79 91
4703 21 23 29 33 51 59 83 87 89 93 99
4801 13 17 31 61 71 77 89
4903 09 19 31 33 37 43 51 57 67 69 73 87 93 99

PRIME NUMBERS FROM 5000 TO 7999

5003 09 11 21 23 39 51 59 77 81 87 99
5101 07 13 19 47 53 67 71 79 89 97
5209 27 31 33 37 61 73 79 81 97
5303 09 23 33 47 51 81 87 93 99
5407 13 17 19 31 37 41 43 49 71 77 79 83

5501 03 07 19 21 27 31 57 63 69 73 81 91
5623 39 41 47 51 53 57 59 69 83 89 93
5701 11 17 37 41 43 49 79 83 91
5801 07 13 21 27 39 43 49 51 57 61 67 69 79 81 97
5903 23 27 39 53 81 87

6007 11 29 37 43 47 53 67 73 79 89 91
6101 13 21 31 33 43 51 63 73 97 99
6203 11 17 21 29 47 57 63 69 71 77 87 99
6301 11 17 23 29 37 43 53 59 61 67 73 79 89 97
6421 27 49 51 69 73 81 91

6521 29 47 51 53 63 69 71 77 81 99
6607 19 37 53 59 61 73 79 89 91
6701 03 09 19 33 37 61 63 79 81 91 93
6803 23 27 29 33 41 57 63 69 71 83 99
6907 11 17 47 49 59 61 67 71 77 83 91 97

7001 13 19 27 39 43 57 69 79
7103 09 21 27 29 51 59 77 87 93
7207 11 13 19 29 37 43 47 53 83 97
7307 09 21 31 33 49 51 69 93
7411 17 33 51 57 59 77 81 87 89 99

7507 17 23 29 37 41 47 49 59 61 73 77 83 89 91
7603 07 21 39 43 49 69 73 81 87 91 99
7703 17 23 27 41 53 57 59 89 93
7817 23 29 41 53 67 73 77 79 83
7901 07 19 27 33 37 49 51 63 93

PRIME NUMBERS FROM 7999 TO 9999

8009 11 17 39 53 59 69 81 87 89 93
8101 11 17 23 47 61 67 71 79 91
8209 19 21 31 33 37 43 63 69 73 87 91 93 97
8311 17 29 53 63 69 77 87 89
8419 23 29 31 43 47 61 67

8501 13 21 27 37 39 43 63 73 81 97 99
8609 23 27 29 41 47 63 69 77 81 89 93 99
8707 13 19 31 37 41 47 53 61 79 83
8803 07 19 21 31 37 39 49 61 63 67 87 93
8923 29 33 41 51 63 69 71 99

9001 07 11 13 29 41 43 49 59 67 91
9103 09 27 33 37 51 57 61 73 81 87 99
9203 09 21 27 39 41 57 77 81 83 93
9311 19 23 37 41 43 49 71 77 91 97
9403 13 19 21 31 33 37 39 61 63 67 73 79 91 97

9511 21 33 39 47 51 87
9601 13 19 23 29 31 43 49 61 77 79 89 97
9719 21 33 39 43 49 67 69 81 87 91
9803 11 17 29 33 39 51 57 59 71 83 87
9901 07 23 29 31 41 49 67 73

Chapter 11

Tables

In the final section of this book a number of tables are included to assist in arriving at a suitable set up for the project in hand. Having purchased a new dividing head a table of possible divisions will be included with it that will be fine in most circumstances. However, a second hand head may have parted company from its manual and should you make one yourself, typically that in chapter 8, arriving at a suitable set up would necessitate recourse to calculation. You may have noticed that I do not refer to "the suitable set up" but to "a suitable set up" this is because in many cases there is more than one method of arriving at the same result, often many methods.

The manual supplied with a commercial head understandably quotes just one set up for each value on the basis that the supplied division plates will remain with the head. However, we all know that this so often is not the case and one plate may go missing. For many values this will not be a problem as the required division will be achievable using another plate. For this reason the published tables include every set-up that provides an achievable division, typically, table one, for a 40 : 1 dividing head, lists six set-ups for 24 divisions.

Based on Division Plate sizes

The tables can of course only cover a range of division plate numbers and are based on those commonly supplied with a smaller head. These are 15, 16, 17, 18, 19, 20, 21, 23, 27, 29, 31, 33, 37, 39, 41, 43, 47, and 49.

Possible divisions not included

To limit the size of the tables for publication some values have been omitted. Values below 20 are not included as they can easily be arrived at by observation and some simple mathematics. Obviously, values of 15 and above will use division plates having that number of holes, say for 17 use the plate with 17 holes, the holes traversed being equal to the head's ratio, say 40 for a 40:1 head. Typically for other values, for 7 divisions the 21 hole plate would be the obvious choice. Values above 200, 360 excluded, have been omitted on the basis of their limited application.

Observing table one, for a 40 : 1 head, it will be seen that no values are given for either 20 or 40 divisions. This is because

one turn of the input will rotate the output one division, and is obviously achievable with any one of the eighteen division plate values. Twenty will similarly be arrived at with two full turns per division. For the same reason 20, 30 and 60 are omitted from table two and 30, 45 and 90 from table three.

Column Headings

The column headings D, P, T and H relate to the following

D. Division achieved

P. Number of holes on the division plate to be used

T. Number of full turns at the input

H. The number of additional holes to be traversed after the number of full turns, if any.

R. Ratio (gear size) Applies to table 4 only.

Worm/Wormwheel ratios

Tables 1, 2 and 3 are for the commonly available ratios of 40 : 1, 60 : 1 and 90 : 1. However, the head for home workshop construction in chapter 8 can have 9 additional ratios, for example, 35 : 1 using the 35 tooth changewheel. Publishing 9 other lists in full is obviously impractical and in any case most of the possible divisions with these will also be achievable with the 40 : 1 and 60 : 1 ratios listed in tables one and two.

For that reason, table four includes only those additional values possible, quoting for each value the gear ratio required to achieve it. They are all relatively high numbers and mostly numbers of little use. One hundred and twenty-five is though on the list that will be useful for that dial required for an 8 TPI lead screw.

Of greater significance for the workshop owner who constructs the dividing head is that in addition to the above extra divisions he or she will get 23 further divisions (51 being the lowest) using the 60 :1 ratio that are not available with the 40 : 1 ratio, being by far the most common commercially available dividing head.

Three Gear Dividing Head

The dividing head in chapter 7 uses either a single gear or additionally a pair of gears providing the same function as a worm and wormwheel. The ratio will though be lower, typically gears of 60 and 20 having a ratio of 3 : 1, or complex, gears of 65 and 45 having a ratio of 13 : 9.

No table is provided for the single gear as in this case the results should be obvious. Two examples being, a forty tooth gear providing 2, 4, 5, 8, 10 and 20, a thirty-five tooth gear 5 and 7. Again the table is limited to 16 to 200 plus 360 but also leaving out divisions that can easily be achieved with a single gear.

1. DIVISIONS POSSIBLE USING A 40:1 DIVIDING HEAD

D	P	T	H												
21	21	1	19	41	41	0	40	75	15	0	8	132	33	0	10
22	33	1	27	42	21	0	20	76	19	0	10	135	27	0	8
23	23	1	17	43	43	0	40	78	39	0	20	136	17	0	5
24	15	1	10	44	33	0	30	80	16	0	8	140	21	0	6
24	18	1	12	45	18	0	16	80	18	0	9	140	49	0	14
24	21	1	14	45	27	0	24	80	20	0	10	144	18	0	5
24	27	1	18	46	23	0	20	82	41	0	20	145	29	0	8
24	33	1	22	47	47	0	40	84	21	0	10	148	37	0	10
24	39	1	26	48	18	0	15	85	17	0	8	150	15	0	4
25	15	1	9	49	49	0	40	86	43	0	20	152	19	0	5
25	20	1	12	50	15	0	12	88	33	0	15	155	31	0	8
26	39	1	21	50	20	0	16	90	18	0	8	156	39	0	10
27	27	1	13	52	39	0	30	90	27	0	12	160	16	0	4
28	21	1	9	54	27	0	20	92	23	0	10	160	20	0	5
28	49	1	21	55	33	0	24	94	47	0	20	164	41	0	10
29	29	1	11	56	21	0	15	95	19	0	8	165	33	0	8
30	15	1	5	56	49	0	35	98	49	0	20	168	21	0	5
30	18	1	6	58	29	0	20	100	15	0	6	170	17	0	4
30	21	1	7	60	15	0	10	100	20	0	8	172	43	0	10
30	27	1	9	60	18	0	12	104	39	0	15	180	18	0	4
30	33	1	11	60	21	0	14	105	21	0	8	180	27	0	6
30	39	1	13	60	27	0	18	108	27	0	10	184	23	0	5
31	31	1	9	60	33	0	22	110	33	0	12	185	37	0	8
32	16	1	4	60	39	0	26	115	23	0	8	188	47	0	10
32	20	1	5	62	31	0	20	116	29	0	10	190	19	0	4
33	33	1	7	64	16	0	10	120	15	0	5	195	39	0	8
34	17	1	3	65	39	0	24	120	18	0	6	196	49	0	10
35	21	1	3	66	33	0	20	120	21	0	7	200	15	0	3
35	49	1	7	68	17	0	10	120	27	0	9	200	20	0	4
36	18	1	2	70	21	0	12	120	33	0	11	360	18	0	2
36	27	1	3	70	49	0	28	120	39	0	13	360	27	0	3
37	37	1	3	72	18	0	10	124	31	0	10				
38	19	1	1	72	27	0	15	128	16	0	5				
39	39	1	1	74	37	0	20	130	39	0	12				

2. DIVISIONS POSSIBLE USING A 60:1 DIVIDING HEAD

D	P	T	H
21	21	2	18
21	49	2	42
22	33	2	24
23	23	2	14
24	16	2	8
24	18	2	9
24	20	2	10
25	15	2	6
25	20	2	8
26	39	2	12
27	18	2	4
27	27	2	6
28	21	2	3
28	49	2	7
29	29	2	2
31	31	1	29
32	16	1	14
33	33	1	27
34	17	1	13
35	21	1	15
35	49	1	35
36	15	1	10
36	18	1	12
36	21	1	14
36	27	1	18
36	33	1	22
36	39	1	26
37	37	1	23
38	19	1	11
39	39	1	21
40	16	1	8
40	18	1	9
40	20	1	10
41	41	1	19
42	21	1	9
42	49	1	21
43	43	1	17
44	33	1	12
45	15	1	5
45	18	1	6
45	21	1	7
45	27	1	9
45	33	1	11
45	39	1	13
46	23	1	7
47	47	1	13
48	16	1	4
48	20	1	5
49	49	1	11
50	15	1	3
50	20	1	4
51	17	1	3
52	39	1	6
54	18	1	2
54	27	1	3
55	33	1	3
57	19	1	1
58	29	1	1
62	31	0	30
63	21	0	20
64	16	0	15
65	39	0	36
66	33	0	30
68	17	0	15
69	23	0	20
70	21	0	18
70	49	0	42
72	18	0	15
74	37	0	30
75	15	0	12
75	20	0	16
76	19	0	15
78	39	0	30
80	16	0	12
80	20	0	15
81	27	0	20
82	41	0	30
84	21	0	15
84	49	0	35
85	17	0	12
86	43	0	30
87	29	0	20
90	15	0	10
90	18	0	12
90	21	0	14
90	27	0	18
90	33	0	22
90	39	0	26
92	23	0	15
93	31	0	20
94	47	0	30
95	19	0	12
96	16	0	10
98	49	0	30
99	33	0	20
100	15	0	9
100	20	0	12
102	17	0	10
105	21	0	12
105	49	0	28
108	18	0	10
108	27	0	15
110	33	0	18
111	37	0	20
114	19	0	10
115	23	0	12
116	29	0	15
117	39	0	20
120	16	0	8
120	18	0	9
120	20	0	10
123	41	0	20
124	31	0	15
126	21	0	10
129	43	0	20
130	39	0	18
132	33	0	15
135	18	0	8
135	27	0	12
138	23	0	10
140	21	0	9
140	49	0	21
141	47	0	20
145	29	0	12
147	49	0	20
148	37	0	15
150	15	0	6
150	20	0	8
155	31	0	12
156	39	0	15
160	16	0	6
162	27	0	10
164	41	0	15
165	33	0	12
170	17	0	6
172	43	0	15
174	29	0	10
180	15	0	5
180	18	0	6
180	21	0	7
180	27	0	9
180	33	0	11
180	39	0	13
185	37	0	12
186	31	0	10
188	47	0	15
190	19	0	6
192	16	0	5
195	39	0	12
196	49	0	15
198	33	0	10
200	20	0	6
360	18	0	3

3. DIVISIONS POSSIBLE USING A 90:1 DIVIDING HEAD

D	P	T	H
20	16	4	8
20	18	4	9
20	20	4	10
21	21	4	6
21	49	4	14
22	33	4	3
23	23	3	21
24	16	3	12
24	20	3	15
25	15	3	9
25	20	3	12
26	39	3	18
27	15	3	5
27	18	3	6
27	21	3	7
27	27	3	9
27	33	3	11
27	39	3	13
29	29	3	3
31	31	2	28
32	16	2	13
33	33	2	24
34	17	2	11
35	21	2	12
35	49	2	28
36	16	2	8
36	18	2	9
36	20	2	10
37	37	2	16
38	19	2	7
39	39	2	12
40	16	2	4
40	20	2	5
41	41	2	8
42	21	2	3
42	49	2	7
43	43	2	4
46	23	1	22
47	47	1	43
48	16	1	14
49	49	1	41
50	15	1	12
50	20	1	16
51	17	1	13
54	15	1	10
54	18	1	12
54	21	1	14
54	27	1	18
54	33	1	22
54	39	1	26
55	33	1	21
57	19	1	11
58	29	1	16
60	16	1	8
60	18	1	9
60	20	1	10
62	31	1	14
63	21	1	9
63	49	1	21
65	39	1	15
66	33	1	12
69	23	1	7
70	21	1	6
70	49	1	14
72	16	1	4
72	20	1	5
74	37	1	8
75	15	1	3
75	20	1	4
78	39	1	6
80	16	1	2
81	18	1	2
81	27	1	3
82	41	1	4
85	17	1	1
86	43	1	2
87	29	1	1
93	31	0	30
94	47	0	45
95	19	0	18
96	16	0	15
98	49	0	45
99	33	0	30
100	20	0	18
102	17	0	15
105	21	0	18
105	49	0	42
108	18	0	15
110	33	0	27
111	37	0	30
114	19	0	15
115	23	0	18
117	39	0	30
120	16	0	12
120	20	0	15
123	41	0	30
126	21	0	15
126	49	0	35
129	43	0	30
130	39	0	27
135	15	0	10
135	18	0	12
135	21	0	14
135	27	0	18
135	33	0	22
135	39	0	26
138	23	0	15
141	47	0	30
144	16	0	10
145	29	0	18
147	49	0	30
150	15	0	9
150	20	0	12
153	17	0	10
155	31	0	18
160	16	0	9
162	18	0	10
162	27	0	15
165	33	0	18
170	17	0	9
171	19	0	10
174	29	0	15
180	16	0	8
180	18	0	9
180	20	0	10
185	37	0	18
186	31	0	15
189	21	0	10
190	19	0	9
195	39	0	18
198	33	0	15
200	20	0	9
360	16	0	4
360	20	0	5

4. DIVISIONS POSSIBLE WITH RATIOS OTHER THAN 40:1 AND 60:1

D	P	T	H	R
77	21	0	15	55
77	33	0	30	70
77	33	0	15	35
77	49	0	35	55
91	21	0	15	65
91	39	0	30	70
91	39	0	15	35
91	49	0	35	65
112	16	0	5	35
112	16	0	10	70
119	17	0	10	70
119	17	0	5	35
121	33	0	15	55
125	15	0	3	25
125	15	0	6	50
125	15	0	9	75
125	20	0	4	25
125	20	0	8	50
125	20	0	12	75
133	19	0	5	35
133	19	0	10	70
143	33	0	15	65
143	39	0	15	55
153	17	0	5	45
154	33	0	15	70
161	23	0	5	35
161	23	0	10	70
169	39	0	15	65
171	19	0	5	45
175	15	0	3	35
175	15	0	6	70
175	20	0	4	35
175	20	0	8	70
175	21	0	6	50
175	21	0	3	25
175	21	0	9	75
175	49	0	7	25
175	49	0	14	50
175	49	0	21	75
176	16	0	5	55
182	39	0	15	70
187	17	0	5	55
189	21	0	5	45
189	27	0	5	35
189	27	0	10	70

DIVISIONS POSSIBLE WITH A THREE GEAR DIVIDING HEAD

DIV	TURNS	DG	SG	LG	NOTE	
16	1	40	50	20	*	1
18	1	45	50	20	*	1
21	1	35	25	30		2
22	1	20	50	55	*	
24	1	20	25	30	*	
26	1	20	50	65	*	
27	1	45	25	30		2
28	1	20	25	35	*	
32	1	20	25	40		
33	1	30	50	55		
36	1	20	25	45		
39	1	30	50	65		
42	1	30	25	35		
44	1	20	25	55		
48	1	30	25	40		
49	1	35	50	70		
52	1	20	25	65		
54	1	30	25	45		
56	1	35	25	40		
63	1	35	25	45		
64	1	20	25	40		3
66	1	30	25	55		
72	1	30	25	60		
77	1	35	25	55		
78	1	30	25	65		
80	1	40	30	60	*	
84	1	35	25	60		
88	1	40	25	55		
90	1	30	20	60	*	
91	1	35	25	65		
96	1	40	25	60		
98	1	35	25	70		
99	1	45	25	55		
100	1	40	20	50	*	
125	1	50	30	75		
200	3	40	30	50		4
360	7	30	35	60		5

NOTES

1 USES A STEP UP RATIO, GEAR ON HEAD SPINDLE SMALLER THAN THE DRIVER
2 USE EVERY OTHER TOOTH SPACE
3 USE FORKED DETENT AND EVERY TOOTH AND SPACE
4 DIVIDING HEAD OUTPUT ROTATES THREE FULL TURNS
5 DIVIDING HEAD OUTPUT ROTATES SEVEN FULL TURNS

* THESE DIVISIONS CAN BE ACHIEVED USING A FORKED DETENT WITH A SINGLE GEAR

HEADINGS

DIV	DIVISION ACHIEVED
TURNS	NUMBER OF WORKPIECE TURNS
DG	DIVIDING GEAR
SG	SMALL GEAR COUPLED TO DIVIDING GEAR
LG	LARGE GEAR MOUNTED ON HEAD SPINDLE